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THE TORES OF SATURN.

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FOR POPULAR ASTRONOMY.

A little before sunrise on June 19th (1907), a new phenomenon was detected at Flagstaff in the saturnian ring system. The date was the first occasion that Saturn had been looked at there at this opposition. The planet was morning star at the time, raised just above the dimming of the dawn in the Eastern sky, having but recently passed quadrature and was in that curious phase of its aspect when it seems to have lost its ring. Next to the singularly Jupiter-like appearance it presented in consequence and the striking oblateness of figure it revealed the most conspicuous feature of the disk was the dark band which then belted the planet's equator. In this band which first caught and then kept attention for the detail it disclosed, centered the interest. For the band, which was in truth the shadow of the rings upon the ball, suggested rather one of the planet's belts and at the same time exhibited features of a peculiar character. The shadow, far from being dark, was only moderately dusky and furthermore presented when first looked at a curious tripartite appearance. On more careful scrutiny its lack of uniformity proved to be due to a narrow black line that threaded it medially throughout its length, the black core being perhaps one-fourth as wide as the less dense background upon which it stood. At the same time the rings themselves could with attention be made out as the finest knife-edges of light cutting the blue of space on either side the planet's disk. As the Sun was at the moment 32′ north of the plane of the ring-system, while the Earth was 2 degrees 16′ south of it, the two were on opposite sides of the system, which fact combined with its then visibility shows that the rings are never wholly lost in the Flagstaff glass. This black core to the shadow of the rings upon the ball is a phenome-

non which has not previously been observed, nor has it yet been seen elsewhere, although evident to all the observers at Flagstaff.

The planet was not looked at again until October 31, other work occupying the observatory in the meantime. In November, however, it was critically studied. The dusky band was evident as in June and the black line made core to it as before, being plainly perceptible to all the observers. On the 12th and 13th of the month I measured both with the filar micrometer, the measures on the latter date being the more numerous and exact, for the band was then measured between the micrometer threads, outside them and from center to center of the same, while the pencil-like core was estimated in terms of the thread itself. The mean of the measures with the suitable corrections applied gave:

for the whole shadow, 0″.46
and for its black core, 0″.10.

The band was tinged a faint cherry red (Nov. 5); rather more strongly so than the planet's own belts which could be seen both north and south of it two; on either hand, the temperate the fainter, and the tropical fainter in the center than on the sides.

The black medial line running through it was by no means even. It both undulated slightly and showed irregularities of outline, one black bead in especial being noticeable upon it about halfway from the planet's center to its (the planet's) eastern limb (Nov. 13 — 7^h). The line also seemed not quite central in the belt but a little nearer its northern edge. The Sun was now 1° 39′.5 south of the ring-plane while the Earth was 50′ north of it, so that both bodies were now again on opposite sides of it, having respectively shifted across.

The rings themselves were equally visible, in fact, were now easy objects, although as before only the edge of their plane was presented to the eye. But in addition to the general line of their light, agglomerations were plainly discernible on them. The condensations, puffs of light upon a golden thread, were symmetrically placed, two on either side the ball, and continued observation showed them to be permanent in position. Micrometric measures were made upon them by both Mr. Lampland and by me from November 3rd to November 9th. Before seeing to what they commit us we will review what had previously been done on the subject.

Apparent agglomerations or thickenings of the rings have been noticed by several observers since the time of Herschel; by Bond, Wray and Struve in especial.

At the last occasion when the rings were presented edgewise to the Earth they vanished as observed with the Lick telescope by Barnard, not becoming visible till October 30, 1901. When they did appear he noticed that the ring could first be seen at a distance of about 2″ from the edge of the disk; also that the two halves on either side were not the same; and lastly he perceived two bright knots on the western one. In explanation of the knots Barnard assumed that he saw two of the inner satellites; but as Seeliger from whom the above account is quoted quaintly remarks "Mimas only could be in question and it might raise difficulties to explain both knots by it."

Seeliger then goes on to give his own explanation of the knots first propounded by Olbers to wit: that they are due to ansal forelengthening of the brightest portions of the ring from traverse of them by the line of sight. From his study of the relative lustre of different parts of the ring system, both observational and theoretic, he deduced for their apparent maxima:

$$\left.\begin{matrix}1.60\\+\ 1.98\end{matrix}\right\}$$ in radii of Saturn from the planet's center.

Barnard published no measures of the positions of the knots but from his drawings Seeliger deduced for them =

$$\left.\begin{matrix}1.60\\+\ 1.94\end{matrix}\right\}$$ in radii of Saturn from the planet's center

while the outer edge of ring A from Barnard lay at 2.22 radii and Seeliger's calculated value at 2.30.

Bond's earlier explanation seems to have been that the knots were caused by the seeing of the outer edge of the ring reinforced by the inner edge of its neighbor where the two turned at their ansae, the rings being slightly opened to the line of sight.

Now at Flagstaff this last November, the positions of the thickenings in the rings were as I have said not only observed but measured so that we have quantitive data to go on. These data from my measures, with which those of Mr. Lampland substantially agree, are—

	November 9. 1907.	$8^h\ 25^m$ to $8^h\ 50^m$ In seconds of arc from the nearer limb	In equat. radii of Saturn from the planet's center	Corr. for irradiation
RIGHT mean of				
3 measures	Inner edge of inner thickening	1″.00	1.11	
2 "	Outer " " " "	3″.94	1.43	
2 "	Gap (most conspicuously vacant spot)	5″.36	1.58	
3 "	Inner edge of outer thickening	6″.92	1.75	
4 "	Outer " " " "	8″.51	1.92	
LEFT				
2 measures	Inner edge of inner thickening	1″.15	1.12	1.13
2 "	Outer " " " "	4″.22	1.46	1.47
5 "	Gap (most conspicuously vacant spot)	5.58	1.60	1.61
3 "	Inner edge of outer thickening	6.53	1.71	1.72
2 "	Outer " " " "	8.46	1.91	1.92

At the same time measures of the span of the whole ring gave:

Mean of			Cor. for irradiation
2 measures	On the right, measured from the nearest limb, reduced to equat. radii from the planet's center.	2.164	2.16
1 "	On the left, measured from the nearest limb, reduced to equat. radii from the planet's center.	2.145	2.16
4 "	From W. end to E. end visible; double measures, reduced as above	2.191	2.20

The equatorial radius, also measured, came out:

Mean of
2 measures Nov. 9. 9″.245
corresponding to a diameter of 17″.38 at distance 9.5389
Nov. 3. 9″.388
corresponding to a diameter of 17″.49 at distance 5.5389
giving a mean diameter of 17″.44 " " "

Compare now with these distances from Saturn those of the latest measures of the ring-system (See 1901).

From Saturn's center in radii of the planet.

Outer radius of the outer ring, A.		2.32
Encke's division.		2.19
Inner radius of outer ring A.		2.01
Cassini's division.		
Outer radius of ring B.		1.95
Inner radius of ring B.		1.50
Outer radius of ring C.		1.50
Inner radius of ring C.		1.19
Planet's radius.	(17.″24)	1.00

Measures by other observers of the system give for our present purpose substantially the same result.

From the known dimensions of the ring-system, several interesting points are at once deducible from the Flagstaff measures. First it is evident that the rings in November could not be followed quite to the outer limit of ring A as that stretches to 2.25 or 2.30 radii from the center of the planet according to whose measures of the system we adopt, while the measured breadth now was at most 2.20. This implies that the outer part of ring A has less thickness than the rest, for we cannot refer the effect to the less breadth of ring it traverses there being intersected by the line of sight, since the Earth was on the opposite side of the ring-system from the Sun. The average width of the thread of light upon which the agglomerations were strung was by comparison with the black core of the shadow not over eighty miles.

Secondly: The present measures indicate that the rings approach the body of the planet closer than they have been measured before.

Thirdly: The measures of the positions of the agglomeration show that Olber's explanation of them, endorsed by Seeliger, fails to account for the appearances.

Fourthly: These positions point to another explanation of some interest; and

Fifthly: This latter explanation proves also to account for the phenomena of the shadow and incidentally to answer a query propounded by Seeliger on previous observations of it.

To make this clear we will begin by quoting Seeliger upon the observations and deductions on the last occasion when the rings were presented as now edgewise to the Earth.

"Before the ring begins to be visible, it must disclose itself as a dark stripe across Saturn's disk. This was a fact seen and drawn by Mr. Barnard. He found on October 22, (1891) for the breadth of the dark band 0″.51 and for the position of its middle point from the north limb (of the planet) 7″.40′; from the south one, 6″.56. Mr. Barnard asserts that the measured breadth entirely agrees with the ephemeris data. I find, however, for an elevation of 1° 41′ for the Earth above the plane of the ring's width to be 0″.16 or 0″.24 according as the bright ring alone is considered or the dark ring is included as well; [This quantity being the breadth of the ring-system into the sine of the angle of elevation of the Sun above the plane of the rings.] On the contrary I find very good

agreement between the observations and the data for the position of the dark band of 7″.64 and 6″.72 from the north and south limits respectively, and of 7″.60 and 6″.76 if the dark ring be also comprised. The above remarked divergence between observation and theory demands explanation, since Mr. Barnard on October 29 found an even greater breadth of the dark band of 0″.65."

Now taking up first the shadow phenomena seen at Flagstaff, calculation shows that the shadow of the whole ring-system including the crepe ring, with the Sun as on November 9 (1907), 1° 39′.5 above the ring-plane, would be 0″.26 wide only. The position of the Earth does not sensibly change this. Now the shadow was nearly twice as wide as this, being 0″.46. Such then, as Seeliger rightly concluded, cannot be its cause. Nor can the dusky band be the penumbra of the dark umbral core as that would be only 0″.05 in width, a quantity indistinguishable in fact by the eye. Neither projection nor penumbra then can account for the effect and we must look out of the plane of the rings for an explanation. The only supposition to tally with the facts is that in the black core we are looking at the shadow of such parts of the ring-system as are practically plane, chiefly ring A, and in the dusky shadow about it through particles situated above and below that plane lying in the other rings. In other words, that ring B and ring C are for the most part not flat rings but tores.

Turning now to the phenomena of the rings themselves, the agglomerations on the Olbers-Seeliger theory of their showing should, as computed in the same memoir by Seeliger be found at 1.60 and 1.98 radii of Saturn from the planet's center, for these are the points where the line of sight from the Earth traverses the greatest ansal breadth of the rings at their densest.

Instead, however, of being so found the present thickenings occur in striking contrast to this, the maxima showing where the minima should and the minima where the maxima would be; since their centers are situated at 1.27 and 1.83 with a conspicuous gap at 1.60 and another falling-off at 1.92 outward. It is not, then, to line of sight massing from particles in one plane that the observed effect is due.

But the moment we let our thought wander out of the plane we light upon an explanation which satisfies the phenomena. For suppose portions of the rings to be not flat rings but tores, that is, rings after the manner of anchor-rings, encir-

cling the planet. Then, viewed edgewise, such a tore would make its presence perceptible by humps of light in two patches symmetrically placed on either side of the planet, to wit, at its ansae where the sight-line would penetrate the greatest amount of it. The agglomerations, then, can represent tores, but cannot represent flat rings.

Thus we are led by the phenomena presented by the rings to the same explanation to which those of the shadow conducted us. Furthermore, it is to be remarked that the line of argument in each case is independent of the other. For in the one case, in the shadow, we are reasoning on what we note from a transverse viewing of the tores, in the other, the rings themselves, from a longitudinal aspect of them in the bright agglomerations. As the two deductions lead to the same result each gains corroboration from the other.

The rings of Saturn, then, are not flat rings but for the most part tores, some hundreds of miles across, thus many times exceeding in thickness the portions approximately plane for which the Flagstaff observations indicate a cross section of eighty miles. They are only to be seen in their true character on the occasions of edgewise presentation to the Earth for as the ring opens the increased apparent breadth of the of the whole system masks the slight difference between the tores and the plane sections still further obliterated by the greater irradiation of the last.

It seems necessary to suppose that we see through the tore to its partially illuminated side, for from observations made or published since this article was written it appears that the agglomerations disappear when either the Sun or the Earth passes through the plane of the rings.

Thus Mr. Lampland's observations of the rings gave,—

December 31, Agglomerations visible.
January 1, Ansae too faint to detect structure.
January 3 and 4, Ansae continuous.
January 7, No agglomerations. Rings easily seen.

Earlier observations by Aitken at the Lick July 23—October 12, show that no agglomerations were seen between those dates. See Barnard to the same affect.

Since this article was written Barnard has published his observations with his explanations. His explanations, however—for he gives two,—one that the eye sees through the underside of the rings and that such light is greatest where the rings are densest, the other the exact opposite, that the light is most

where the ring is least crowded—are self-condemning on several counts, one for instance that the inner condensation does not fall by his own showing on the ansal position of any part of ring A, but wholly on the crape ring. Each explanation might account for one agglomeration alone but for that very reason fails for both. The presence of the gaps is another fatal objection to them.

As seen at Flagstaff, under the same seeing that disclosed the dark core to the ring's dusky shadow, the agglomerations were fairly continuous, though uneven, for the whole length of them measured on November 9th. Their vertical width was about 0″.20 while that of the continuous ring was about 0″.02 giving for the width in the main plane of the rings some 80 miles or 130 kilometers.

The appearance of these tores was at times exquisitely beautiful. Particles on them would shine out like diamonds in flashes of light to fade the next moment, while others farther along twinkled in turn. Nor did the satellites in the least conflict with them; for the divergence of the line to the Earth from the ring-system's plane, slight as it was, sufficed to throw the satellites above or below it against the background of the sky.

Such are the facts of observation. Interesting as they are in themselves they gain both in import and in cogency when the system is considered from the point of view of celestial mechanics.

Mechanically considered, knowledge of the character and constitution of the rings has had an eventful history. Although Cassini had suggested that they might not be solid, they were universally so deemed until Laplace took up the subject. He first showed that the rings could not be, as they appear, wide solid rings, inasmuch as the strains due to the differing attraction of Saturn for the several parts must disrupt them. Peirce then proved that even a series of very narrow solid rings could not subsist and that the rings must be fluid. Finally Clerk-Maxwell demonstrated that even this was not enough and that the rings to be stable must be made up of discrete particles, a swarm of meteorites, in fact. But, if my memory serves me right, Clerk-Maxwell himself pointed out that even such a system could not eternally endure but was bound eventually to be forced both out and in, a part falling upon the surface of the planet, a part going to form a satellite farther away.

Even before Clerk-Maxwell's time Edward Roche in 1848 had

shown that the rings must be composed of discrete particles,—mere dust and ashes. He drew this conclusion from investigations on the minimum distance at which a fluid satellite, or even a solid one of sufficient size, could revolve around its primary without being disrupted by tidal strains.

The dissolution which Clerk-Maxwell foresaw can easily be proved to be inevitable if the particles composing the swarm are not at considerable distances from one another. For a swarm of particles revolving round a primary are in stable equilibrium *only in the absence of collisions.* From the light rings A and B send us, it is evident that they must be pretty closely packed, even allowing for the comminuted form of their constituents. In so crowded a company collisions, due either to the mutual pulls of the particles or to the perturbations of the satellites, must occur. At each collision, although the total moment of momentum of the two particles remains the same, energy is lost unless the bodies be perfectly elastic, a condition not found in nature, the lost energy being converted into heat. In consequence some particles will be forced in toward the planet while others are driven out; the greater number falling in until at last they are brought down upon the body of the planet.

Now the interest of the observations at Flagstaff consists in their showing us this disintegration of the rings in process of taking place. For a mechanical discussion of the problem proves that tores would be raised and that these would lie where the actual tores are observed to be.

One of the chief causes of collision among the particles composing the ring system would be the perturbing action they must suffer at the hands of the satellites. For the disturbing pull of the latter is different for particles at different distances from Saturn and diverse for the same particle in varying positions of its orbit. Even if the bodies constituting the ring were all originally revolving in approximate circles they must from this cause speedily be thrown into ellipses of differing major axes and differently positioned so that collisions would be greatly increased both in number and force. Such collisions would be most frequent and disastrous where the perturbative action of the satellites was greatest. The first thing, then, in our inquiry is to discover where the satellites' action would be most potent.

To evaluate the disturbing action of a body upon a second revolving round a third, the most effective analytic treatment

for our present purpose the discovery of perturbations of long period is by the method of variation of the arbitrary constants. By this artifice first developed by Lagrange the undisturbed elliptic form of the equations expressing the motion is preserved but the elliptic constants are now regarded as variables whose values are determined from the perturbative function, subject to the condition that they shall represent in form both the unperturbed function and its first derivatives or in other words the place and the velocity of the particle as if they were invariable, differing from the actual motion only in their second derivatives or in the change of the velocity brought about by perturbation. The resulting equations are then solved by expansion in a converging series of terms of which enough may be taken to attain any desired accuracy.

The points germaine to our present inquiry are the perturbations in the radius vector. For those alter the mean distance of the disturbed particle from Saturn and therefore its mean motion about the planet,

$$\text{since} \qquad n^2 = \frac{\mu}{a^3}.$$

Now, put analytically, by the method above outlined of variation of parameters, the radius vector of the perturbed body —the disturbed particle in the present case—may be denoted, following Airy's excellent exposition of the subject, by

$$r_1 = \frac{a_1 \ (1 - e_1^2)}{1 + e_1 \cos. \ (\theta_1 - \omega_1)}$$

where the subscripts refer to the variable elements which must then be evaluated in terms of the supposed invariable ones for a given moment. The perturbed longitude is expressed by

$$\theta_1 = n_1 t + e_1 + (2e_1 - \frac{e_1^3}{4} + \text{etc.}) \sin \ (n_1 t + e_1 - \omega_1) + \text{etc.}$$

The variable elements are found in terms of the invariable by means of the equations,

$$\frac{da_1}{dt} = - \frac{2na^2}{\mu} \frac{dR}{de}, \qquad \frac{du_1}{dt} = \frac{3n^2 a}{\mu} \frac{dR}{de},$$

and so on, deduced from the general equations of motion, on the above understanding in which R, the perturbative function =

$$\frac{m^1 r \cos. \ (\theta^1 - \theta)}{r'^2} - \frac{m^1}{\sqrt{[r^{1^2} - 2r^1 r \cos. \ (\theta^1 - \theta) + r^2)]}}$$

m^1 denoting the mass of the satellite, and μ that of Saturn and the particle. The equations when integrated give a_1, n_1, etc. Substituting these, the radius may then be expanded in an ascending series of terms according to powers of the eccentricities and of cosines of multiple arcs of the mean motions of perturber and perturbed by Fourier's series. The resulting expression is composed of terms similar to those in the undisturbed orbit and of others denoting the effect of the perturbation has $a_1 = a +$ etc. The latter are of the typical form:

$$\frac{cn}{\mu} \quad \frac{Pe^x e'^{x_1}}{pn - qn^1} \cos. \overline{(pn - qn^1)\ t - M}$$

or

$$\frac{cn}{\mu} \quad \frac{Pe^x e'^{x_1}}{pn - qn^1} \cos. \overline{((p-1)\ n - (q-1)\ n^1)t - N}$$

where P is a function of a and a^1, the radii vectores of the perturber and perturbed.

The form of these terms shows that they will become considerable in proportion as $pn - qn^1$ is small, since their coefficients are divided by this quantity. Now as nt and n^1t are the mean motions of perturber and perturbed, if these are nearly commensurate there will always be terms of the sort which will be large, namely those in which $\frac{q}{p} = \frac{n^1}{n}$; for p and q are always integers, in consequence of the method of expansion.

The various terms with the argument $(pn - qn^1)\ t$ will have coefficients of different powers of the eccentricities. The lowest of these which can occur in the expressions will be of the order $p - q$. The term therefore, in which $x + x_1 = p - q$ is the term least diminished by the eccentricity coefficient and therefore the most potent in its effect.

From this it is evident that two bodies will mutually disturb each other in their revolutions about a third according as their periods are,

1st — Commensurate.
2nd — Differ by the smallest integer.

The most disturbing ratio is when the periods are

1 : 2 ; 2 : 3 etc.
the next, 1 : 3 ; 3 : 5 etc.
then, 1 : 4 ; 2 : 5 etc.
and so on.

The initial ratio in each line will be the most effective in that line because the cycle of the disturbance will be repeated

in the time it takes the outer body to come again into conjunction with the inner and this for the ratio 3 : 5 for instance will be three times as long as for that of 1 : 3.

The thing can be seen geometrically by considering that the two bodies have their greatest perturbing effect on one another when in conjunction and that if the periods of the two be commensurate they will come to conjunction over and over in the same points of the orbit and thus the disturbance produced by one on the other be cumulative. If the periods are not commensurate the conjunctions will take place in ever shifting positions and a certain compensation be effected in the outstanding results. In proportion as the ratio of periods is simple will the perturbation be potent. Thus with the ratio 1 : 2 the two bodies will approach closest only at one spot, and always there, until the perturbations thus induced themselves destroy the commensurability of period. With 1 : 3 they will approach at two different spots recurrently; with 1 : 4 at three, and so on. The number of points round the orbit at which they will meet is in fact as the sum of the powers of the eccentricities in the lowest coefficient of the terms with the commensurable argument.

We see, then, that perturbations, which in this case will result in collisions, must be greatest on the particles having periods commensurate with those of the satellites. But inasmuch as there are many particles in any cross-section of the ring there must be a component of motion in any collision tending to throw the colliding particles out of the plane of the ring, either above or below it. Such extra-plane particles would, therefore, be most numerous just inside the points of commensurability, because though the moment of momentum is preserved and particles are thus thrown outward from the point as well as in, owing to the loss of energy the waifs must be more numerous on the inside.

Considering, now, the commensurate ratios between the periods of particle and satellite which can enter into the problem, we find these in the order of their potency to be:

With Mimas,	1 : 2,
	1 : 3,
	1 : 4,
With Enceladus,	1 : 3,
With Tethys,	1 : 4.

Such periods of commensurability as 2 : 3 of Mimas and 1 :2, 2 : 3, of Enceladus, do not come into question as they take place practically outside the ring-system. Now calculation shows that the distances corresponding to a period of 1 : 2 of Mimas, 1 : 3 of Enceladus, and 1 : 4 of Tethys, fall in Cassini's division, which separates ring A from ring B. The first or outer tore should therefore occur just inside that division or in the outer part of ring B. Now when we turn to the observations and compare them with the plan of the ring-system we note that this is precisely where it occurs; for the inner edge of Cassini's division lies at 1.92 radii of Saturn from the center of the planet and the outer tore begins at 1.92, thence to stretch inward toward the disk.

Pursuing our inquiry with the next most effective ratio, that of 1 : 3 of Mimas' period, we note that its corresponding distance falls at the boundary of ring B and ring C at 1.50 radii of Saturn from the center. Now it is inside this, to wit, at 1.46 and 1.42, that the inner tore begins. But this is not all. The inner tore is much longer than the outer one. We turn, therefore, to the next most potent ratio, that of 1 : 4 of Mimas' period, to find that its distance falls at 1.24. So that here a second perturbation prolongs the action of the first. The two together thus account for the greater length of the inner tore.

The remarkable way in which theory thus explains observation is of interest and the more so from involving a case of celestial mechanics interesting in itself.

Thus the rings are falling in upon the planet under the action of the satellites, of Mimas aud Enceladus in particular. But there is nothing catastrophic about the occurrence. The moons of Saturn have been busied disintegrating the rings since that appendage was formed. The far fact can be sounded by the plummet of our analysis though the action fail of certain record in our telescopes for the length of the period involved in its working out. To penetrate time is so much harder than to see through space.

Yet even so there are comparative observations which seem to point to it. If we tabulate Jacobs' measures made in 1856 with those of Barnard and of See we detect an apparent encroachment of the dark ring toward the body of the planet. Thus—

Distance from Saturn in radii of the planet.

		Jacobs.	Reduced to same diameter as later ones and cor. for irradiation.	See.	As measured at Flagstaff 1907.
Outer	A	(40″) 2.23	2.28	2.32	[2.28
Encke	"	2.12	2.17	2.19	2.17
Inner	"	2.00	2.03	2.01	1.99
Outer	B	1.94	1.97	1.95	1.92
Inner	"	1.47	1.51	1.50	1.48
Outer	C	1.47	1.51	1.50	1.48]
Inner	"	1.26	1.30	1.19	1.12
Radius		(17″.94) 1.00	1.00	(17″.2.4)1.00	(17.44)1.00

But this though suggestive is inconclusive because the greater power of modern objectives would produce the same seeming stretching in of the crepe ring toward Saturn's limb. But the fact stands as securely proved mathematically as if its advance had already been recorded.

But there is another outcome to the analysis beside the end to which it eventually leads and that is the disclosure of the method by which that end is brought about. This is that the Flagstaff observations exemplify and in this that their importance lies. They show the action of disintegration in process of taking place. To him who appreciates the analysis by which man's mind stretches out beyond the now and here to the then and there, the tores speak of the rings' decay and dissolution as prophetically as if time were so shortened for him that he could mark the very particles tumbling in to rest forever upon the planet's self. For that beautiful appendage that now diadems Saturn making him by far the most immediately impressive object in the heavens he is destined eventually to lose. Robbed of it by his own retinue, the satellites, he will circle round the Sun a discrowned orb. The condition that makes him at present so superb a sight has for its characteristic instability and this trait dooms it to pass away. Though there is nothing catastrophic about the changes now going on, their slowness of action clothes them with all the greater import. For the very stateliness of the process renders its inevitableness the grander to the mind of man.

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A PRACTICAL METHOD OF DRAWING ELLIPSES.

WILLIAM H. PICKERING.

For Popular Astronomy.

In Popular Astronomy 1894 I 248 Professor Burnham states that in his opinion the best method of drawing ellipses is by the old method using a thread or wire and two needles. In this I quite agree with him. In order to vary the major axis he employs a sewing machine needle varying the length of the thread by drawing it through the eye. I have found another simple method which involves the use of a pin and two needles. In this case the thread is tied into a loop which is thrown over the needles, and given a single turn about each one. If we wish to draw the upper half of an ellipse, the major axis being horizontal, the pin is placed inside the loop between the needles and slightly below them. By simply varying the distance between the pin and the line joining the needles we can vary the major axis of the ellipse by as small or large a quantity as we choose. This arrangement is very convenient, as it enables us to allow for the slight stretching of the thread which almost always occurs in practice. I usually use one pencil to draw the ellipse, and another to carry the thread down to the bottom of the needles. By holding the drawing pencil at the proper angle the thread maintains itself upon it at a constant height of one or two millimeters.

In constructing an ellipse it is more accurate to determine the length of the thread by the minor rather than by the major axis. The former should therefore always be laid off before the curve is drawn. The semi-minor axis $b = a\sqrt{1 - e^2}$ where a is the semi-major axis, and e the eccentricity, or the distance from the focus to the center divided by the semi-major axis.

Harvard College Observatory,
January 17, 1908.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

Part II. (Continued.)

SPECIFIC STATEMENTS OF FUNDAMENTAL CONCEPTS CONCERNING THE CONSTITUTION OF MATTER.

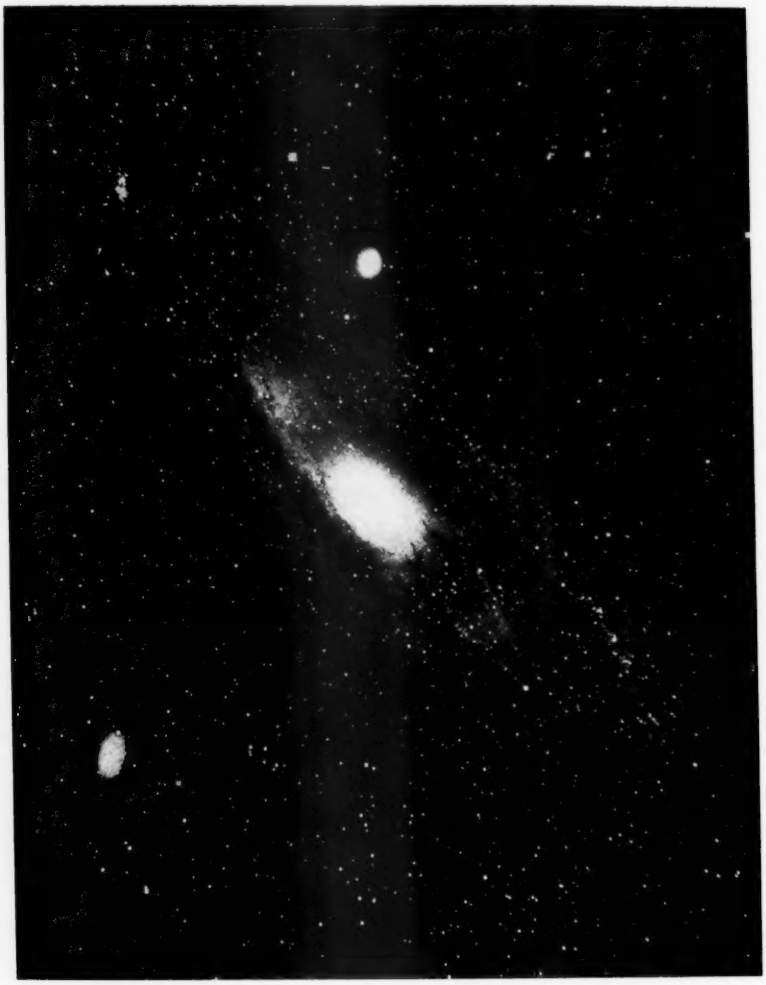
FOR POPULAR ASTRONOMY.

It is reasonable to infer, therefrom, that some of the gaseous matter ejected from volcanoes consists of pure carbon vapor pressed upward from great depths, and that what are commonly considered as "flashes of lightning," playing in the clouds overhanging the craters, are simply the results of the sudden oxidation, and flashing into flame, of this carbon vapor, the solid and liquid, or viscous, matter—ashes, lava etc.—being forced upward to the crater, through the ducts of the volcano, by the pressure of the gases confined in the depths below.

The black cloud that suddenly descended from the riven side of Mont Pelée, in Martinique, W. I., on that awful day in May 1902, and fell upon the populous city of St. Pierre, near the base of the mountain, most probably contained within itself, or was partly composed of, pure carbon vapor together with divers hydrocarbon gases which, when mixed with the proper proportion of atmospheric oxygen, flashed into flame with the rapidity of an explosion, and in a moment, not only killed, practically, all the population of that city of more than 30,000 people, but also destroyed the city itself, shattering even its most substantial edifices; such also was, undoubtedly, the cause of the historic catastrophe that befell the cities of Pompeii and Herculaneum in that memorable year 79 A. D. when the pent up gases within the depths of Vesuvius burst their bonds and overwhelmed the people of those cities while engaged in their daily occupations, burying all under many feet of the solid matter ejected from the crater.

Certain of the physical properties of silicon, carbon and possibly *boron*, indicate the fitness of these elementary substances for service as the matter of *solid*, and *very rigid*, nucleus of the Earth: A form of pure silicon is a dark-brown, amorphous powder which *when heated to redness in the absence of air becomes denser* and assumes a *graphitic* appear-

PLATE IV.



GREAT NEBULA IN ANDROMEDA.

[Scale: 1mm=27.″5]

ance, and much the same statement, except as to color, may be made concerning pure carbon. Now, if these substances, in pulverized form, become *denser* when heated to *redness*, or at a temperature of 1000°—1200°, Fahrenheit, under ordinary pressures, we may say, with almost absolute certainty, that, at the internal temperature of 6,340°, which is about that of the electric arc, and under the enormous pressure of the 66 miles of matter above it, and in the obvious absence of air, the density of both silicon and carbon,—assuming these to constitute the nucleus of the Earth below the "crust" thereof,—would easily be about double that of the same matter at the surface and under the ordinary conditions of pressure and temperature, and therefore equal to the present mean density of the Earth which is 5.52.

Taking the mean surface density as 3.25, if we assume that it increases regularly with the depth, the condition that the mean density of the whole Earth is 5.50 would imply a maximum density of 7.75 for the internal matter, or nucleus, and this is the density of *iron*, a fact which, of late, has led some physicists to assert that this metal is the chief constituent of the *nucleus*, and that the Earth is an "iron globe," but we know that iron constitutes only a small percentage of the superficial matter and there is no reason to assume that conditions in this respect are materially different in the interior, while, from what has been stated above concerning silicon and carbon, particularly in regard to density, quantity, solidity and rigidity under extremely high temperature and pressure, all necessity for assuming a *metallic* nucleus is obviated. We know that the approximately pure species of carbon called the "diamond" is of considerable density (about 3.5) and of the *greatest hardness*, and that it has been artificially produced from carbonaceous matter, *under conditions of great pressure and high temperature, in the absence of air*, in the electric furnace the temperature whereof is practically the same as that of the Earth's internal matter, as above determined. Pure silicon, under the same conditions, would also constitute a substance of probably vitreous nature and extreme hardness, and it is also known that the somewhat similar element *boron* is chemically obtainable as a very hard substance called "adamantine boron."

Therefore, in such substances under said conditions of temperature and pressure, we have materials well fitted to con-

stitute the *solid*, and *extremely rigid*, nucleus of the Earth, which, as the late Lord Kelvin many years ago pointed out, must be a solid *more rigid than steel*, in order to resist the distorting stresses brought to bear upon it continually, by the tidal forces of the Moon and the Sun.

I have also computed the initial radius (R_p) of each of the secondary condensations in the primitive solar nebula, which formed the nuclei of the other planetary members of the solar system, and the maximum temperature (T_p) generated by the compression of these gaseous nuclei to the dimensions of the planets at the present time, by the same methods employed in the case of the Earth, through the equations (d_1) and (e_1) derived from my theory, and the results are tabulated as follows:

TABLE II a.

Planet	Density	Initial Radius	Internal Absolute Temperature
Neptune	0.88	5,604	3,266°
Uranus	0·94	3,307	3,411
Saturn	0.72	1,747	2,864
Jupiter	1.32	1,234	4,281
Mars	1.93	472	5,640
Earth	2.66	300	6,800
Venus	2.84	177	7,120
Mercury	3.09	180	7,934

In the first column of numbers are set forth the densities (D_p), and in the second, the radii (R_p) of the secondary nebulous masses—now the planets,— at the time of beginning of condensation, the present semidiameter of each planet being referred to as 1, while in the third column are the maximum absolute temperatures (T_p), generated by the compression of each planet down to its dimensions at the present time, and these are also the maximum internal temperatures at certain depths below the surface in each case, while the temperatures referred to the "zero" of the ordinary Fahrenheit scale are deducible therefrom by subtracting 460° from each tabulated temperature.

An inspection of this table discloses some interesting and striking facts from which some important conclusions concerning mooted astronomical questions may be deduced.

Thus it is noticeable that the density and the temperatures in the case of each of the four great outer planets, Jupiter, Saturn, Uranus and Neptune are *low* when compared with the similar quantities in the case of the four inner, and smaller, planets Mars, Earth, Venus and Mercury, the densities in all the former cases being less than that of the Sun which is

known to be a gaseous body still undergoing compression according to the laws of the thermodynamics of gases and, therefore, still heating at an *increasing* rate. Now the reason for this marked difference between the two sets of planets becomes apparent when we consider the values of the initial radii, (R_0) set forth in the second column of numbers, because the values therein given are very *large* for the great planets aforesaid, as compared with those of the four smaller planetary bodies of which the Earth is one; in other words, the volumes of the secondary nebulous masses, at the beginning of the process of formation of the greater planets, were vastly greater than those forming the four smaller bodies, and therefore *more time has been required* for the former to condense to their present dimensions, and as result they are yet in the gaseous state and still compressing and heating as is the Sun, a fact to which both photometric and spectroscopic observations bear witness.

While the spectroscope shows that these planets shine, principally, by reflected sunlight, the photometric comparisons indicate that the intensity of their light is distinctly greater than can be attributed to reflected solar radiance alone, whence it is inferred that they shine partly by their own intrinsic light and are therefore, still in the gaseous, compressive and *sun-like* stage of development, and increasing in temperature; but, as the spectroscope indicates, they are enveloped by very deep, vapor-laden atmospheres that obscure the actual conditions on their surfaces, which conditions are considered to be somewhat similar to those now existent upon the Sun's surface,–the "belts" "redspot" etc,, on the disk of Jupiter being very significant on this point.

A number of the most eminent observers have noted abnormalities in the light of the planet Uranus, and also the fact that the outermost known planet, Neptune, does not exhibit a clearly defined, planetary disk, it appearing more like a small planetary nebula.

The fission of the several masses of the surface matter of the primitive solar nebula in, and from, which the secondary condensations forming the nuclei of the four great outer planets were developed, quite obviously occurred long ages before that of the matter whence the Earth, Mars, Venus and Mercury were formed, and therefore it has been commonly inferred that the four greater planets aforesaid are much older, and in a more advanced state of development, than the Earth and the

three smaller planets just named; but this does not necessarily follow. It may well be that the beginning of the process of planetary condensation, or formation, was not in the same order, as to time, as that of the fission of the belts of matter in which they had their origin, from the parent solar nebula, but may have varied greatly; the beginning of the formation of the nuclei of the four outer planets may have been about at the same time, or *even later* than that in the case of the Earth and the three other inner planets. Moreover, the *mass*, or the quantity of matter, of each of the four larger planets is much greater than that in the case of the Earth and the three other bodies, as was also the original volume and the initial radius thereof, or the distance through which they have contracted to their present dimensions, and all these factors must have operated to prolong the period of formation relative to that in the case of the Earth, while, on the other hand, the relative surfaces of each of the four outer planets is much greater than that of our globe, and the radiation of heat and the rate of contraction therefore greater, and the time of reduction of said planetary bodies to their present dimensions, consequently *relatively less* than in the case of the Earth.

The *masses* of Jupiter, Saturn, Uranus and Neptune are respectively, 300; 90; 13 and 17 times that of the Earth, and their initial radii, set forth in the second column of Table IIa, are respectively 4.1; 5.7; 11.0 and 18.7 times the initial radius in the case of our globe, while, on the other hand, the respective surfaces relative to that of the Earth are 114; 79; 18 and 22.

These relative masses and initial-radii may be regarded as *plus* factors with respect to the time, or duration, of the process of planetary formation, and the relative surfaces as *minus* factors; therefore by taking the product of the *plus* factors in each case and dividing it by the corresponding *minus* factors there result, in whole numbers, 11; 7; 8 and 14 which, *ceteris-paribus*, may be regarded as the times required for the formation of the four greater planets relative to the time in the case of the Earth; in other words, these planets are respectively, only $\frac{1}{11}$; $\frac{1}{17}$; $\frac{1}{8}$ and $\frac{1}{14}$ as far advanced in the stage of development, as the Earth. The relative time of *beginning* in each case is, as stated above, *problematical*, but if we take, empirically, the arithmetical series 2; 3; 4 and 5 as representing, approximately, the relative times of beginning

of planetary formation in each cast-off belt of matter, and multiply by the fractional quantities set forth just above, the products $\frac{1}{8}$; $\frac{1}{2}$; $\frac{1}{2}$ and $\frac{1}{3}$ will indicate, in some wise, the stages of development with respect to the Earth. In any case it is quite evident, from what has been stated, that both observation and my theory indicate that the planets Jupiter, Saturn, Uranus and Neptune are still in the gaseous, or formative, stage of development, or, as we may term them, "unfinished worlds". As yet, these planets,—particularly Jupiter and Saturn with their systems of satellites—are comparable to miniature solar-systems, and, as has been done in the case of the Sun, the absolute surface temperature may be taken as one-half the maximum internal temperature in each case set forth in Table IIa, this absolute surface temperature being, in the case of Jupiter 2140 degrees; Saturn, 1335 degrees; Uranus 1705 degrees and Neptune 1633 degrees and by deducting 460 degrees from these values there result for the respective surface temperatures, referred to the zero of the Fahrenheit scale, in the ordinary manner; Jupiter 1680 degrees; Saturn 975 degrees; Uranus 1245 degrees Neptune 1173 degrees.

Now, the wave-length (λ) at the more refrangible end of the spectrum of a surface heated to the absolute temperatures above set forth, is given by the following, analytically derived, equation of my theory: $\lambda = 7886 \times \frac{1438^{\circ}}{T}$; (*g*), the wave-length so found marking the upper limit of the spectrum, in each case. Taking the values of the absolute surface temperature (T), given above, and substituting it in equation (*g*) for each planet, there results, as the wave-length, in the case of Jupiter; 5300 tenth metres; in that of Saturn 7900; for Uranus 6650 and for Neptune 6946; from which it appears that if the true surface of Jupiter could be observed through the spectroscope, the spectrum exhibited would have its upper-limit near the E line in the "yellow," the predominating color being "reddish-yellow," or "orange," and I think that the observations upon the "red-spot" and other surface phenomena only dimly disclosed through the heavy superficial clouds or vapors enveloping the "giant planet," bear testimony to the truth of my theoretical deductions in this connection. Under the same conditions of visibility, the upper limit of the spectrum in the case of Saturn would be nearly at the A line, or at about the beginning of the "red," and in the case of Uranus near the C line, and in that of Nep-

tune near the B line—both the latter spectra being therefore confined to the "red" also.

We must therefore, conclude that, since the surfaces of these planets are so hot, and are still increasing in temperature, no form of life, either animal or plant, can possibly exist upon these four great members of the solar system but may be developed thereon, in the far distant future, after these planets shall have attained their maximum temperatures, and have subsequently gone through all the processes that have brought the Earth to its present habitable condition. Of the three other companions of the Earth, the planet Venus which is almost identical, in dimensions, with our globe, appears to possess a considerable extent of atmosphere laden heavily with vapors, or clouds, which, while they obscure the real surface, reflect the sunlight most brilliantly when Venus is in proper position relative to the Sun and the Earth.

While observing the "transit of Venus," with my 3-inch refractor at Washington, D. C. on December 6, 1882, I noticed that shortly after the time of "first contact" when the greater portion of the disk of the planet was outside the Sun's limb, it was distinctly outlined by a narrow, pearly aureole which, if not caused by light from the coronal background, must have been due to refraction and reflection of the Sun's light, by an atmospheric envelope, of considerable density and extent, surrounding the planet. This phenomenon was seen by other observers, not only on that occasion, but also in previous "transits," when conditions were favorable, and from certain thereof observations of this phenomenon it has been quite well determined that the atmosphere of Venus is very similar to that of our globe.

The internal, and surface, temperature and the vapor-laden atmosphere, taken in connection with the dimensions and *mass* of the planet Venus with respect to the Earth, all lead to the conclusion that the surface conditions on Venus are much the same as those that existed upon the Earth in the Palæozoic, or Primary Age of geological history, when the surface of our globe had cooled sufficiently to allow precipitation of the aqueous vapor of the atmosphere thereupon and the existence of the most primitive elementary forms of plant and animal life thereon, at or about the ending of the Huronian-Cambrian period, or the, beginning of the Silurian, as is evidenced by the fossil fauna and flora of

that remote epoch which (according to computations based upon the "law of radiation" derived from the principles of my general theory) was, very approximately, 50 millions of years ago at which time the surface temperature, due to the internal heat of our globe, was about 150 degrees Fahrenheit, a temperature adapted to the existence and propagation of certain forms of vegetable and animal life, particularly in the waters that then covered the surface of the Earth more extensively than at the present time, or before "the waters were gathered together in one place, and the dry land appeared"—to quote the words of Genesis.

Much the same course of reasoning, and conclusions therefrom, are applicable to the case of the planet Mercury, so that, of all the eight known planets of the solar system, only the Earth can be regarded as fitted by reason of its physical condition, both internal and superficial, to be the abode of living organisms such as now exist upon it, the question as to the planet Mars being still an open one which has, of late years, been receiving considerable attention—both scientific and pseudo-scientific—and we must await further observational developments; in fact this question concerning the habitability of Mars is more of popular, than of scientific, interest in this connection.

If the process of contraction of each of the four great planets, Jupiter, Saturn, Uranus and Neptune were to continue from the density (D_p) at the present time, until the density (2.66) of the principal part of the superficial matter of the Earth is reached and the planetary matter passes from the *gaseous* to the *viscous*, or approximately solid, state, the final radius (r) of each planet aforesaid may be found from the expression $r = \left(\frac{2.66}{D_p}\right)^{-\frac{1}{3}}$, derived from equation (d_1) set forth in the preceding part of this paper, the numerical value of r being in terms of the respective planetary semidiameters which, in each case, are taken as 1, while the final maximum absolute temperature (T_m) will be given by the following expression; $T_m = T_p + \frac{T_p}{3}(r^{-2} - 1)$ derived from the equation (e_1) of said part.

The density (D_p) of each of the four planets is given in Table IIa, as is also the maximum temperature (T_p) at the present time, a solution of the two equations, set forth just above, giving the following results:

Jupiter	Final	Radius	0.7893	Max.	Temperature	6571°	Increase	2290°
Saturn	"	"	0.6469	"	"	5154	"	2285
Uranus	"	"	0.7070	"	"	5686	"	2275
Neptune	"	"	0.6916	"	"	5543	"	2277

Taking average values for these four planets, it is apparent that the intrinsic absolute temperatures should increase by 2280 degrees, reaching finally a maximum of 5800 degrees, whereas the present maximum absolute temperature, in the case of the Earth, is 6800 degrees, as stated in the preceding part. This former temperature is about that at which pure *silicon* would pass from the *gaseous* to the *viscous* state, while the latter temperature is about that at which pure *carbon* would undergo the same change of state, a mean of the two temperatures, or 6300 degrees, would therefore represent that at which a combination of silicon and carbon, in equal proportions by weight, would be at the transition point, and this temperature does not differ materially from that which I have obtained in the manner described in the preceding part of this paper, the depth at which this maximum internal temperature is reached being, under the conditions just stated, 61 miles, whereas in the former case it was stated as 66 miles, so that, when everything is taken into consideration, with regard to the peculiar and complex conditions involved in the problem, the determinations in this connection may be regarded as quite definitive and sufficient.

Regarding each of the four great planets as similar to the Sun, in respect to the development of heat therein by the compression of its gaseous mass, the surface temperatures, when each planet will have reached the limit of gaseous compression, in the far distant future, will be one-half the maximum internal temperatures attained at that time, as set forth above, the absolute temperature of the surface of Jupiter becoming then 3285 degrees Fahrenheit; that of the surface of Saturn 2577 degrees; that in the case of Uranus 2843 degrees and that of the surface of Neptune 2772 degrees. Introducing these values of T in the equation connecting temperature (T) and wave-length (λ), set forth in a preceding paragraph, there results λ 3452 as the shortest wave-length (in tenth-meters) in the case of Jupiter; λ 4400 in that of Saturn; λ 3989 in that of Uranus, and λ 4091 in the case of Neptune; that is these would be the limiting wave-lengths at the more refrangible end of the spectrum, in each case, for a solid surface heated to the temperatures aforesaid and radiating in the atmosphere under the normal conditions, provided there were no absorp-

tion by surrounding gaseous matter, or in the transmitting medium itself, and they would mark the extent of the spectrum in each case. Under these conditions the spectrum of Jupiter would be lengthened to beyond the H line, or to the ultra-violet part; that of Saturn to approximately the G line in the "indigo," while in the case of Uranus and Neptune the upper end of the spectrum would be found in the vicinity of the H line, or at about the end of the "violet."

Following the same course of reasoning, and applying the same method, in the case of the Sun as that used to determine the final radius and corresponding maximum absolute temperature for the four great planets, by substituting D_s or the density of the Sun at the present time, for D_p the planetary density, and T_s instead of T_p for the maximum absolute temperature of the internal matter of the solar globe, instead of the planetary temperature, D_s being 1.4 and T_s 13,400—the following results are found. The Sun should undergo gaseous compression until its semidiameter will have contracted to 0.8074 of its present length, or from 432,170 miles to 348,930 miles—through a distance of 83,240 miles,—and until its internal absolute temperature has become 15,790 degrees Fahrenheit, an increase of 2390 degrees, and since the absolute temperature of the solar surface matter, under such conditions, is one-half the internal, its value would then be 7,895 degrees, or about 1,195 degrees greater than at the present time, according to my determinations. Finally, since in the process of contraction two-thirds of the heat that would be generated by *adiabatic* compression must be radiated, and lost, from the mass, only one-third, or 2390 degrees being retained, the temperature loss (T_e) must be 4780 degrees.

These conditions in the case of the Sun are fraught with great, and practical, import not only to solar physics, and astro-physics, but also preëminently to meteorology, and may lead to a modification of some views now held by physicists working in these particular fields of research. In the first place, the loss of heat, (T_u) measured in thermal units of any system, such as the "pound degree, Fahrenheit" (which is represented by one pound avoirdupois of water heated through one degree of the Fahrenheit scale), is expressed by the equation; $T_u = W.s.\ T_e$; (1) in which W represents the weight of the Sun (lbs. avoir.) and s, the specific heat of the solar matter, T_e representing the temperature

loss which is 4780 degrees as aforesaid. Regarding the Sun as a gaseous mass, the specific heat (s) may be taken at 0.20 which is about a mean between the value of the specific heat of a gas at "constant pressure," and the specific heat thereof at "constant volume," so that sT_e, in equation (1), is equal to 956°, while the weight (W) of the Sun, (which is easily found since we know the volume of the solar globe (in cubic feet) and the density, or weight per cubic foot, is 4351×10^{27} lbs, and therefore, the product of this number by the value of sT_e, stated just above, is 4160×10^{30} thermal units this being the value of T_u which represents the quantity of heat lost by the Sun in contracting, from its present dimensions, down to the limit of greatest compression, through the distance of 83.240 miles of its radius.

Now, the quantity of heat, measured in thermal units as in the case just stated, received from the Sun, on unit surface (one square foot for instance) at the Earth, has been very accurately determined by means of pyrheliometric instruments, and this quantity multiplied by the square of the distance from the Earth to the Sun's surface, measured in terms of the radius of the solar globe—taken as 1—gives the number of thermal units radiated from one square foot of the Sun's surface, in any given time—one year for instance—and since the total area of said surface, (in square feet) is known, we will have by multiplying it by the radiation, per square foot, the total radiation of solar thermal energy, per annum, which is 1455×10^{28} thermal units and since the total loss of heat during the compression through the 83,240 miles of the radius would be, as aforesaid, 4160×10^{30} units, it follows that the number of years required for the consummation of the process of compression through the distance of 83,240 miles of the Sun's semi-diameter, which number is obtainable by a division of the total heat loss,—4160×10^{30} thermal units—by the total radiation per annum, which is, as above stated, 1455×10^{28} thermal units, would be 286 years, *provided that the radiation of heat proceed uniformly from every portion of the Sun's surface.*

Since the diameter of the solar globe would be thus reduced by 166,480 miles in 286 years, *under the aforesaid condition*, the rate of contraction would be 582 miles per annum, or nearly the $\frac{1}{150}$ part of the diameter in a century, a conclusion so at variance with known facts of solar physics that it amounts to a veritable *reductio ad absurdum*,

but one that leads directly to certain concepts which I regard as among the most important ones of my general theory, viz: those that have reference to terrestrial atmospheric conditions as affected by correlated solar and planetary influences, and which are, therefore, of great practical importance as they serve to elucidate some heretofore suspected, but obscure, relationships between solar and planetary conditions and certain phenomena of meteorology, directly affecting the comfort and welfare—if not the very existence—of mankind.

Saint Paul, Minnesota.

To be continued.

A NOTE ON THE RELATION OF ASTRONOMICAL SECONDARY NEGATIVES TO THEIR ORIGINALS.

ROBERT JAMES WALLACE.

For Popular Astronomy.

The use of glass positives is a matter of every day practice in the preparation of plates recording astronomical (and physical) data. These positives are in many instances made directly from the original negatives, and, where the object is to direct attention to fine filamentous structure or detail, such as the outlying nebulosity farthest removed from a nucleus, or other detail, of low relative contrast, then it is the general practice to resort to local (chemical) reduction on the film of the positive.

There are, however, negatives of certain subjects in which it is not possible by this single remove to introduce sufficient contrast to clearly show the structure which can be traced with a practiced eye, upon the original negative. In this event, it is necessary to make from the original a secondary negative, in which, by the minimum of exposure and the maximum of development, (together with judicious chemical reduction), the relative contrasts are exaggerated. By such means one is enabled to render visible in the positive, or subsequent engraving, those particular characteristics which would otherwise remain merely records apparent to the eye of the individual privileged to examine the original negative.

It must, however, be evident, that no matter what care is taken, or how expert an individual may become in the hand-

ling of copying processes or reducing solutions, used either locally or in "flat" reduction, the resultant positive can not but (under the circumstances) be utterly false in its relative photographic light values. The result is, that except for "form", the new negative or positive is neither a record of visual or photographic relative intensity.

Further advance along the line of photographic plates does not promise a betterment of these conditions, because no matter how much they may be improved, or rendered more adaptable, there will always be nebulous structure, or faint lines, which lie at the extreme limit of the underexposure portion of the characteristic plate curve, while astronomical negatives continue to be made.

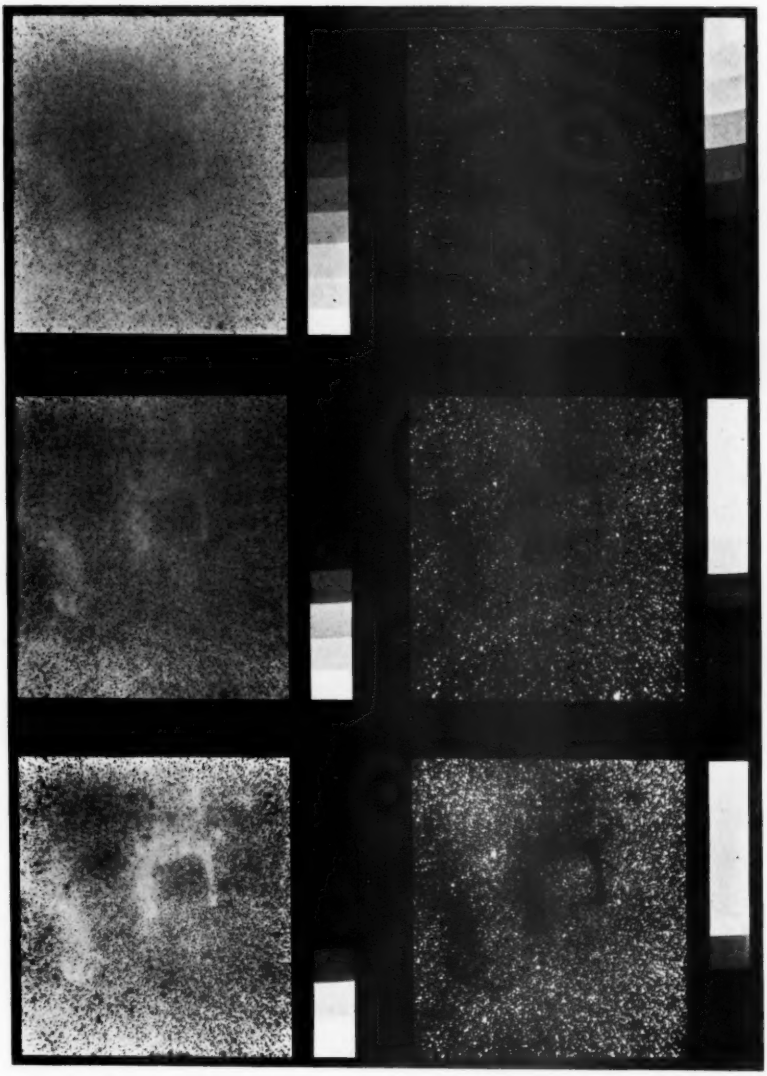
Under the assumption then, that conditions in this direction indicate a fair degree of stability, it is advisable that some method of estimating the change in the photographic light value between the later illustration and the original negative be suggested. This is more particularly the case where the photograph purports to be a record of scientific accuracy, and in which relative photographic intensity holds a prominent place.

The alteration in the ratios existing between the densities of a photographic negative due to chemical reduction, was first pointed out definitely in the classical research of Hurter and Driffield;* it is desirable however, that a record be obtained embracing the gradual action of the reducer upon the plate under conditions approximating actual use in astronomical work. A negative was therefore made by development of an exposure in the revolving sector-disk machine, and after measurement in the spectrophotometer its curve was plotted. A standard reducing solution† being then made up, the plate was placed therein, and rocked for 2 min. 30 sec., it was then washed, dried, and again measured and plotted. Subsequent reductions and measurements were now given in three steps of 2 min. each, followed by two further reductions for 3 min. each, and one action for 5 min. The reducing solutions were made up fresh for each operation, and the film was always washed and dried before measurement. The resultant curves are shown in Figure 1 where the heavy continuous line indi-

* Jour. Soc. Chem. Industry. May 31, 1890. p. 462.

† Potassium ferricyanide and sodium hyposulphite in proportion of 1:10 200 cc. combined solution used at a time; size of plate 3¼x1½ inches.

PLATE I.



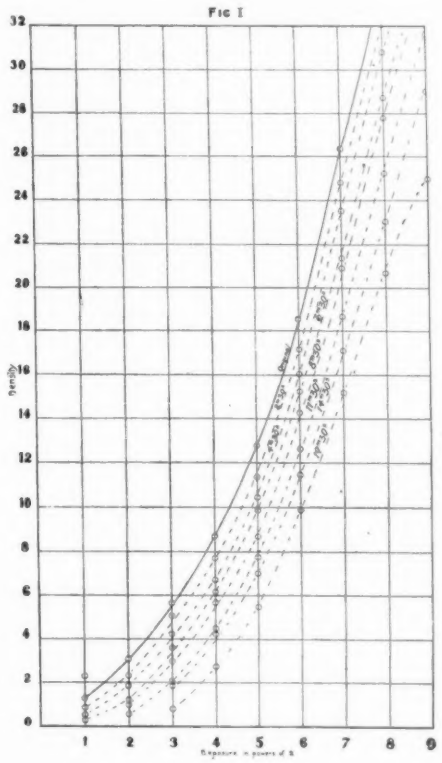
BLACK HOLE IN MILKY WAY.
(R. A. $19^h\ 38^m$ δ $10°46.5$)

CHANGE IN RELATIVE LIGHT-VALUES
WITH INCREASE IN CONTRAST.

POPULAR ASTRONOMY, PLATE V, No. 153.

cates the original negative, and the dotted lines show the action of the reducing solution for the times indicated. The disappearance of the lower densities will be readily marked.

If there should be placed in position adjoining the original, a supplementary small negative containing a scale of densities, and this scale-plate be impressed on all subsequent copies, negative or positive, undergoing precisely the same treatment



as does the body of the plate, then the measurement of the scale upon the last plate of the series, will, in conjunction with its original, give a difference which represents the value of the photographic light change.

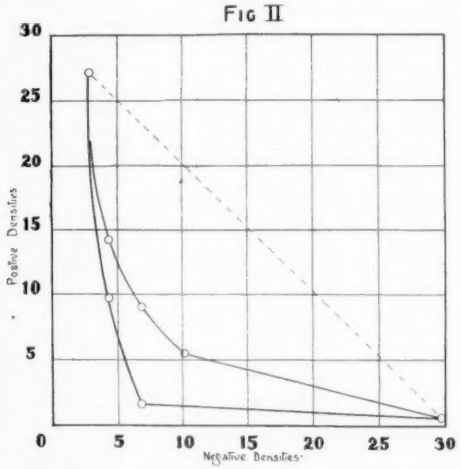
Calling the densities of the original D_1, and those of the same negative after reduction D_2, then the change in the ratios is tabulated thus:

Expos.	D_1	Ratio	D_2	Ratios
1	.1318			
2	.3086			
3	.5624	1.0	.0780	1.0
4	.8720	1.55	.2736	3.51
5	1.2800	2.27	.5454	6.99
6	1.8554	3.30	.9906	12.7
7	2.6354	4.69	1.5184	19.5
8	5.3956 (?)	9.57	2.0644	26.5
9			2.4954	32.0

Were the densities of the reduced negative proportional to the original, then the *ratios* would be similar no matter what the values of the densities.

Referring to the actual employment of the method, there is shown in Plate I (*a*), the original negative* and the original scale plate, together with a positive reproduction of the same

FIG II



(*b*). From this positive was made the secondary negatives *c*, and *d*. For the production of negative *c* a Seed "23" plate was made use of while negative *d* was made upon a Cramer "Transparency" plate, which possesses a higher development factor than the "23". Both plates were developed in a hydrochinone contrast developer, the "Transparency" plate being pushed to the practical limit of chemical action.

Examination of these resulting negatives showed a wide difference in relative contrast and density, which was further

* My thanks are due to Mr. F. W. Jordan for the use of this negative.

accentuated by reduction with ferricyanide and hypo. Absolutely no local reduction was given, but the action of the solution was allowed to proceed evenly upon the respective plates and which, of course, acted equally upon the adjoining scale-plates. The inclusion of positive plates *e*, *f*, (which are exposed and developed to reproduce as exactly as possible, tones truly the inverse of those in their accompanying negatives) merely serve to illustrate the values obtained.

From measurement of the original scale-plate, and also of that resulting in the secondary and tertiary positives, the accompanying curves were plotted, Figure 2. This method of plotting was first suggested by Hurter & Driffield,* wherein the ordinates represent densities of the *positive*, while the abscissæ correspond to the *negative* densities. As is obvious, (and pointed out by these investigators), if the positive densities be truly the inverse of the negative, then the curve would be represented as a straight line. The amount of departure from the straight line condition indicates the value of the difference.

So long as this method of reproduction is utilized then tremendous shortening of the tone-scale will inevitably follow. Making use of a different type of reducing solution (ammonium persulphate for example) is not allowable on work of this class, because one should then undo a very considerable amount of the effect which was striven for in the exposure and development of the subsequent plates from the original, viz: increase in the underexposure portion of the characteristic curve of the plate. We are purposely and intentionally altering the tone-values because it is just that alteration which is desired. It remains, however, that it would seem advisable that there should be some means of indicating just what change has taken place in the light values, and it follows that such change should be capable of expression, and further, that every illustration serving as a record of scientific data which is printed from, other than the original negative, should bear in such reproduction, a copy of a tone-scale showing both the "before and after" effects, and thus point the way for correction to true values when the knowledge of such values is needful.

Yerkes Observatory.
January 17, 1908.

* Relation between photographic negatives and their positives. Jour. Soc. Chem. Indust 1891. p. 100.

A NIGHT MIRAGE.

WILLIAM E. SPERRA.

For Popular Astronomy.

While engaged in the observation of variable stars on the evening of April 3, 1907, a most peculiar and interesting atmospheric phenomenon was noticed by me at 8h 15m. While observing the field U Geminorum, a patch of light in the constellation of Hydra was seen by averted vision, appearing something like a comet or as the Praesepe cluster does to the naked eye. There was a slight haze in the air, plainly perceptible to the eye but which did not interfere with the definition only to blot out the fainter stars.

When first seen it was about a degree due east of δ Hydra. It soon became evident that the star and patch of light were separating the nebulous light drifting east of the star, or rather, as a few minutes showed it to be stationary, and that it was the diurnal motion of the star that caused the separation. At first it was only nebulous with a somewhat brighter center, but soon became elongated about 2° to 3°, and about 15′ wide. At times it would almost disappear and then suddenly get much brighter, generally with a rift in the center. In the telescope it appeared with two distinct condensations or nebulous knots with nebulosity extending outward in opposite directions, appearing like two comets with tails extending in opposite directions.

As already stated it soon became apparent that this strange light was stationary nearly in the meridian and about the height of the equatorial circle. Settings were made with the telescopes for position. The first setting at 8h 20m showed an approximate position: 3° 18′ E. of meridian and 2° 30′ N. declination. A later setting showed a decrease in the altitude of 2°. At about 9h 17m, a second light (which for convenience we will call B and the first A) appeared 8° 15′ to the W. and 4° 15′ to the S. of the first setting for A, giving for the position of B, 5° 0′ W. of meridian and 2° 15′ declination; but as the declination of A had decreased 2°, the relative difference in declination was only 2° 45′. These equatorial measures reduced to altitude, give for the zenith distances 39° 41′ for A, and 43° 45′ for B.

At first it was puzzling how to account for the apparitions, but they were no doubt reflections of the blast furnaces con-

nected with the rolling mills at Newburg. Usually the light from these furnaces shows as red illumination on the clouds or sky, generally flashing, lighting the southern sky, sometimes half way to the zenith. But not a trace of this was to be seen now.

At 10h 10m the haze had become so dense as to obscure all but the very brightest stars, and when A made its appearance–which occurred at intervals of about twenty-five minutes–it was fully five degrees in length, and the flashes were visible emanating from it. Unfortunately no settings were made at this time, as I had removed the telescope to the house, and so cannot tell which way from the observed position the extention occurred. At 10h 45m it was about ten degrees in length, with many bright patches, but mostly brighter near bottom with sharp central line extending toward the zenith.

There was also a round patch of nebulous light SW. of the zenith. At 9h 45m it was just west and below the Praesepe Cluster. At 10h 25m it was east and above. This was continually visible, and no doubt was due to a similar cause.

While having under consideration a discussion as to the probable cause of the phenomenon, I was favored with a second apparition under slightly different conditions on the night of April 18. There was a dense haze all the evening so that only the very brightest of the stars were visible, thus being different from the night of April 3, except for the concluding observations of that evening. First observation at 8h 20m with Regulus on the meridian, and instrument was oriented by means of this star. First setting gave for A's Dec. 8¾ degrees south, and the hour angle as 3½ degrees east. At first it appeared as a nebulous patch of light, as on the evening of April 3. At 9h two distinct centers appeared four degrees apart, with an extreme elongation of 5½ degrees. The upper half was nearly twice as long as the lower half. Settings gave for the positions of upper and lower centers as —5° and —9° respectively.

At 9h 15m light A appeared triple, extreme length being now 9°. Lower image appears essentially the same at each apparition, and settings show its center to be fixed at about —9°, and all elongations being upward. The upper images appear more linear and run into one another. At 9h 40m A is double and its lower image is quite linear, being two degrees long, measuring one degree on either side of located

center. Light B appeared several times, but for an instant only, so no measures could be made of it.

Presuming that this phenomena was a reflection from the lower surface of an air stratum, a preliminary determination for the height of the reflecting surface was made. The furnace A (the origin of light A) is about 4.26 miles south from here. Using the first determination of the zenith distance of A, viz., 39°, the height of the stratum was 2.63 miles. Using the second determination, viz., 41°, the height of the stratum was 2.45 miles, showing that the reflecting stratum fell .18 of a mile between the two observations. Using A's measures on the night of April 18, the height of the reflecting surface was 1.76 miles.

What now was the cause or the conditions that produced these reflections, if such they were. Were they of the order of a mirage, or was the cause similar to that which produces halos? If of the former nature, was the reflection from the under surface of a denser or rarer stratum? That it was from the surface of a denser stratum seems to be indicated from the fact that astronomical definition was good, there being but the slightest scintillation of the stars, and that followed to the zenith. But if so why should the elongations of as much as ten degrees occur? If we suppose this surface to become ruffled in any way, then the elongations are a result of the disturbed surface, for who has not noticed the line of light resulting from the reflection of the Sun on the surface of disturbed water, then again where there was a series of bright patches, each one may have represented a distinct image of the furnace fire, being reflections from an undulatory surface.

A fact that may have an important bearing as to the cause, is that the lowermost image always appeared first, and as it increased in brightness, the others would appear. Then as evidenced from the night of April 18, the lowermost image was stationary, all elongations or multiplications starting from this point, were extended upwards. The elongations and multiplications thus invariably appearing as a function of the increasing brightness and density of the haze. Now if this was a true mirage, though of a compound nature, the upper images should appear similar to the lower, though with relative features reversed; but the fact is they had but little resemblance to the first or lower one, except when it would first appear. When first seen on April 3,

while the haze was very light, the image at its brightest with the rift in the center, appeared not unlike a mirrored picture of what was actually taking place at the furnace mouth, flames made up of innumerable incandescent particles pouring forth, usually in two opposite directions.

The conclusion seems to be that the lower image was a true mirage, but that the upper images and extensions were the result of reflections or refractions from ice crystals of which the haze, no doubt, was composed. And, as the haze deepened or became lower, its modifications of the mirage became more intensified so as to alter the character of the reflections, and the lineal effect was the result, as noted in the last observation of the first night.

Cleveland, Ohio.
January 27, 1908.

SOME OPPORTUNITIES FOR ASTRONOMICAL WORK WITH INEXPENSIVE APPARATUS. II.*

GEORGE E. HALE.

Now let us consider the case of the prominences. If we have available a small spectroscope like that admirable little instrument designed by Evershed, or one made by Thorp,† or a still simpler home-made instrument, and attach such a spectroscope to a 4-inch or 6-inch telescope, we have an almost ideal equipment for the observation of the solar prominences. As a matter of fact, an instrument like the 40-inch is wholly unsuited for work of this kind. You will easily see why. If you wish to observe the entire prominence, its image in the focal plane of the 40-inch telescope is usually so large that the slit cannot be opened wide enough to include the prominence without admitting too much light of the sky. Therefore for a study of the general characteristics of prominences, the small instrument has a great advantage over the large one. It was practically out of the question with the 40-inch for us to do systematic visual work on prominences. When the conditions were pecu-

* A lecture delivered by Professor Hale, Director of the Mount Wilson Solar Observatory of the Carnegie Institution of Washington, at the Royal Astronomical Society, Burlington House, London, W., on Wednesday evening June 26, 1907.

† I wish to call special attention to the solar spectroscopes and other inexpensive instruments made by Mr. Thomas Thorp of Manchester. One of these, a polarizing helioscope, has done excellent service on Mount Wilson.

liarly fine we could study the structure of certain prominences, and I never saw anything more remarkable than such details when they came out under the best seeing. But with the spectroscope available, and under ordinary atmospheric conditions, we could not make records of the general form and distribution of prominences that would compare in value with the records obtainable with small telescopes.

It has remained for certain amateurs here in England very recently to show that objects upon the surface of the Sun which escaped many of the earlier solar observers can be observed at any time when the conditions are favorable with a very small instrument indeed. For example, Mr. Buss and Captain Daunt, and, I believe, some others, have been observing the Sun with such instruments, and have been able to see upon the disk dark regions in which the D_3 line is strengthened, which I think have never been recorded before in any systematic way. Observations of the dark D_3 line upon the face of the Sun were formerly mentioned as unusual and rather remarkable phenomena, and certainly, so far as I have ever seen in the literature of the subject, the dark hydrogen flocculi were never recognized upon the Sun by the earlier spectroscopists; but they are seen, at times at least, by those gentlemen to whom I have referred. This I can make quite certain from my own knowledge, because on one occasion, when Mr. Buss had described one of the very peculiar dark hydrogen flocculi—flocculi of this type appear very much darker than the ordinary ones photographed daily with the spectroheliograph—I looked up our photographs of that date, and there was the image recorded by the spectroheliograph precisely as it had been described. So that if I had previously been a little doubtful as to the possibility of seeing these objects with such an equipment, I gave up all doubt after having made that comparison.* One might say that it would hardly be practicable to observe such phenomena in any satisfactory way with a large telescope. A small one is very much more advantageous for work of this kind. As soon as possible we are going to set up a small equatorial for the purpose of seeing these objects and comparing them with our photographs, after having derived the knowledge of the possibility of observing them from the work done by these men in England. But we will not undertake systematic work in this field, as I hope the valuable ob-

* As I understand the matter, only the more conspicuous dark flocculi can be observed visually.

servations now in progress here will be continued. No records are made with the spectroheliograph of the D_3 image of the Sun at present. We have tried experiments, but so far they have not been successful. We ought to be able to photograph the Sun through the D_3 line, but we have not done it yet. The only existing records are those made by the members of the British Astronomical Association. These observations should be made in conjunction with other solar observations, as in fact is being done at the present time. The characteristics of the hydrogen lines are being observed at the same time that these D_3 images are being recorded, so that any relationship between the two may be discovered. I cannot dwell upon this very interesting subject. There is a great opportunity here for further work of high importance.

I must now pass to the question of sun-spot spectra. I need hardly tell those who are present that observations of sun-spot spectra made visually are sometimes far more valuable than those which can be made by photographic methods. Take, for example, the lines in the green region of the spectrum. This photograph will suffice to show them. Here is the *b* group in the spectrum of a sun-spot and also in the spectrum of the photosphere. We see in the spot a large number of fine lines, long ago observed by Young and Maunder, and now being studied with great care. All of these fine lines shown by a powerful instrument photographically can be seen visually with a spectroscope attached to a 6-inch or probably a 4-inch telescope, and many other phenomena which cannot be photographed at all can be seen with a similar equipment. There is a certain advantage in observing such spectra with a larger telescope, provided that the spot under consideration is a small one. But if the spot is a fairly large one (and hitherto no one has had time to observe the spectra of small spots systematically) I think there is no advantage whatever in having a telescope to form the image of the Sun on the slit of the spectroscope; it is merely a question of having an image of moderate dimensions upon the slit, and after that the spectroscope does the work. So that, so far as the spots actually under observation are concerned, a small telescope is quite as satisfactory as a large one for *visual* work on their spectra.

I will return in a moment to the question of the relative advantages of the photographic and the visual method of observing spot spectra; but I want to point out in passing that the 40-inch telescope has certain very definite advantages for

work on the Sun. If one wishes to observe the spectrum of the chromosphere, for example, the advantages of great focal length immediately become apparent. The width of the spectroscope slit is essentially constant; the chromospheric arc must have a certain linear width on the slit in order to permit the base of the chromosphere to be observed, and consequently the spectrum of the chromosphere, as seen with the 40-inch telescope, is a remarkable sight, showing thousands of lines which do not come out with a small focal image of the Sun.

Here we have, then, an illustration of the advantages for certain purposes of considerable focal length. I think it is not so much a question of the telescope's aperture here, because we must not forget, in thinking of the optics of this question, that the brightness of the spectrum (for constant purity) is quite independent of the linear or the angular aperture of the object-glass that forms the image of the Sun, on the slit of the spectroscope.* Perhaps it is well to bear in mind that the brightest solar spectrum one can get is obtained without any telescope whatever to form an image on the slit, but merely with a collimator of suitable angular aperture. But a large solar image is frequently advantageous, and an equatorial telescope of great focal length is necessarily an expensive instrument. The aperture in the case just mentioned is less important than the focal length; but even if the aperture were only 6 inches the focal length unchanged, the tube must still be 64 feet long, and the mounting would cost no less than the mounting of the Yerkes telescope. So if we wish to have an instrument of great focal length, and yet keep down the expense to a reasonable figure, we must use a telescope of a different type. There are many other reasons why we should wish to use a fixed telescope for certain kinds of solar work, although I should be the last to admit that the 40-inch telescope is not an almost perfectly satisfactory machine of its kind. It has, as we have seen, inconveniences and disadvantages for some classes of work, but in other fields its superior qualities become more and more striking day after day as the observer learns to appreciate them. I only wish

* When the focal length of the collimator is limited (as is usually the case in a spectroscope attached to an equatorial telescope), an increase in the angular aperture of the telescope permits the linear aperture of the spectroscope, and consequently the resolving power and the brightness of the spectrum, to be increased up to a limit fixed by the size of the grating available. With a cœlostat telescope, however, the same conditions do not obtain, since the aperture of the spectroscope can be increased by merely increasing the focal length of the collimator.

we could afford to have such a telescope (or even a much smaller equatorial refractor) on Mount Wilson, as it would be of great service for many purposes.

Now let us consider some of the possibilities of the fixed telescope; and let me show, for purposes of comparison, a picture on the screen of the Snow telescope and which is now employed at Mount Wilson. Here is a cœlostat, with mirror 30 inches in diameter. After passing to a second mirror the light is reflected to a concave mirror of 60 feet focal length, which sends it back and forms a large image of the Sun within a laboratory. This is a very simple instrument indeed. The first cœlostat we set up on Mount Wilson was a small one used by the Yerkes Observatory party at the eclipse of 1900, and it was not originally arranged for work of this kind; so we simply built a wooden support for a second mirror, and with the aid of a 6-inch objective of 60 feet focal length we made a telescope which served admirably for our solar work until this one was put on the mountain.

The next photograph shows the spectrograph used with the Snow telescope. It is of the Littrow or auto-collimating type, with slit and plate-holder at one end of a long tube and lens and grating at the other. Light from the solar image, after passing through the slit, falls on the lens 18 feet (its focal length) distant. The rays, thus rendered parallel, then strike the grating and are returned to the lens, which forms an image of the spectrum on the photographic plate, just above the slit (the grating being tipped back a little). Such an outfit (fixed telescope and spectrograph) is an extremely simple thing to build in inexpensive form. Cœlostats, for example, are common nowadays for eclipse work. One might have a cœlostat with a mirror only six inches in diameter and a second mirror about four inches in diameter, and then perhaps a telescope lens of four inches aperture and 40 feet focal length. Such an instrument as that, which could be very cheaply built indeed, would give a large solar image, adapted for many kinds of solar work.

Let me show you in the next slide how we build our spectrographs in actual practice. This is the most powerful spectrograph in use in the laboratories of the Solar Observatory. Here is a little slit I bought from Hilger, the last time I was in London, for a few shillings. All other parts of the spectrograph, except a lens and grating, are of wood, built in a few

hours by a carpenter.* The wooden support for slit and plate-holder stand on a concrete pier, and close an opening through a partition which forms one end of a narrow dark room. Eighteen feet from the slit, within the dark room, is another concrete pier. A sliding wooden support, carrying a lens, and a simple wooden mounting for the grating, stand on this pier, and complete the spectrograph. Owing to the scarcity of gratings, we are fortunate in being able to use one loaned by Professor Ames, of Johns Hopkins University. If we had no reflecting grating, we could buy a replica very cheaply from Thorp, or Wallace, or Ives,† which would give quite as good photographs as we obtain now (though the exposures would be longer, because of the smaller aperture). They might even be better, because our photographs of spot-spectra (made with the similar spectrograph of the Snow telescope) are not what they ought to be, or what I hope they will subsequently become. They would not stand comparison for a moment, so far as perfection of definition is concerned, with those magnificent photographs of the solar spectrum made by Mr. Higgs in the center of Liverpool, under conditions which would ordinarily be called very bad even for a crowded city, with tramcars constantly passing in front of the house. With a spectrograph of his own construction (except the grating), Higgs made the finest photographs of the solar spectrum ever produced; superior, as Rowland would have said, to the best photographs made by himself at the Johns Hopkins University. It is obvious that something other than an expensive instrument is required to make a good photograph. Mr. Higgs has the ability, which others may acquire, to obtain superb definition and exquisite photographs with very simple apparatus indeed.

With a spectrograph of one-inch aperture and ten feet focal length, used with a fixed telescope of four inches aperture and 40 feet focal length, one would be in a position to make good photographs of the spectra of sun-spots.

What, then, are the relative advantages of visual and of photographic work? The next slide shows some photographs.

* Except the plate-holder which is of a standard make.

† As these are not reflecting gratings the auto-collimating spectrograph might in this case give way to one in which a separate camera lens is used. With the angular aperture here considered, well-made simple lenses would obviously serve perfectly well for collimator and camera, the photographic plate being set at the angle required to bring a sufficient range of spectrum into focus.

The upper one is the spectrum of the Sun and the lower one is that of a spot. These photographs are better than visual observations for the determination of the wave-lengths of unknown lines in spot spectra, simply because you can measure the position of a line on the photograph to much better advantage than you can do it visually at the telescope. They are also better for the determination of the relative intensities of the lines, especially the fainter ones. But when you have said that, you have said almost everything that can be said for the photographs, and you have left out of account many of the very important advantages of visual observation. These photographs represent the integrated spot spectrum, as it were. Even with a large image of the spot on the slit of the spectrograph (and you realize here that the principal point of our great focal length is to have a large image of the spot on the slit), we cannot as yet satisfactorily record minute differences in the spectrum corresponding to small details in the spot. If we wish to study these very important differences in the spot, we must do so, at present at any rate, by visual means. For example, Mr. Newall, your President, told me the other day that he had found the spectrum of the outer edge of the penumbra of a spot to have the same characteristic strengthening of the lines that is observed to the umbra, which is a very difficult thing to explain from the standpoint of the hypothesis I have been favoring of late, viz., that the principal cause of the change of the relative intensities of lines in a spot is reduced temperature of the vapors in the umbra. I knew nothing about that; I had not been observing the spot spectrum visually for many years, and in our photographs this phenomenon is not recorded. You see, then, in such a case the decided advantage of visual observations. I might go on to speak of other advantages. For example, suppose there were a sudden change in the spectrum due to an eruption; the chances that one would get a photograph just at that time are small, whereas visual observations necessarily occupy a considerable period of time, during which eruptions might be detected*. Even a few results might be of extreme importance, and would probably be wholly missed in the photographs. Again, the extension of certain lines outside of the

* It is, of course, desirable to take photographs as often as possible, since a photographic record of a marked change in the spectrum, if fortunately obtained, may be much more valuable than the results of a few visual observations made hastily.

spot, upon the photosphere is not recorded at all in our photographs, because of the method we usually employ of excluding from the plate all light except that which comes from the umbra, and perhaps part of the penumbra. We ordinarily get no trace of these extensions, but perhaps the conclusions drawn from the study of such phenomena may have much to do with the final views as to the nature of the spots themselves.

To mention only one other thing, the reversals of spot lines which have been seen by some observers have not been photographed with our present apparatus. Whether they can be photographed in the future remains to be seen. But, without going into this subject of spot spectra any more in detail, you will certainly agree that the visual observer has a superb opportunity, which the photographic observer cannot by any possibility take away from him.

To be continued.

ASTRONOMY IN 1907.

"Accurate and scientific measurement," observed Sir David Gill, in his Presidential Address to the British Association at Leicester, "seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the greatest discoveries of Science have been the reward of accurate measurement and patience, long-continued labor in the minute sifting of numerical results." To the astronomer who spends little time in looking for something new, and a great deal of labor in mathematical reductions, these words will appear a truism; but they would be his apology if he felt it necessary to offer one, for the unsensational character of the year's work in 1907, or in most years. The year was marked by the appearance of five comets, the popular test of astronomical research; by a rich crop of sun-spots; and by an opposition of Mars, which enabled Professor Lowell to assert once again his belief in the objectivity of the doubled Martian Canals. Saturn showed the edge of its rings; and Jupiter was well placed for observation; but otherwise, if we except the opportunities afforded by Sir David Gill's address, the astronomer was not much before the public. A few sentences must be spared for a summary of the address of the Cape Astronomer. He supported his thesis of the importance of accurate measurement, by a reference to the recent measurement, of the wave-length of the red line in the spectrum of cad-

mium; and by showing its importance in furnishing a unit of measurement which appeared to be trustworthy within the one ten-millionth of a metre. He showed the importance of an accuracy of this order when dealing with the problem of measuring a great arc of meridian, such as that which is now drawing to completion in Africa, and which may sometime be joined to Struve's great arc. Other instances which he supplied, had reference to the measurement of the Sun's distance; of observations of Eros; and to the measurement of the speeds of the Sun and of the stars in space. With regard to the Eros observations, it should be noted that the last "circular" (grown to a bulky volume of 150 pages) was circulated in July. The thanks of all astronomers are due to the late M. Loewy (M. Loewy died suddenly in October, immediately after attending a scientific meeting) and the French Government, for their energy and generosity in this matter. From the circular it appeared that fifty-eight observatories took part in the observations. The number of reference stars was 671, and the observations of these numbered in all 35,398; the observations of Eros numbered 6,642. If to these are added the photographic observations of Eros, as well as of the 671 reference stars, and of the 962 comparative stars, we arrive at a grand aggregate of 76,186 observations.

"By patient, long-continued labor in the minute sifting of numerical results the grand discovery has been made that a great part of space, so far as we have any visible knowledge of it, is occupied by two majestic streams of stars traveling in opposite directions. Accurate and minute measurement has given us some certain knowledge as to the distances of the stars within a certain limited portion of space, and in the cryptograms of their spectra has been deciphered the amazing truth that the stars of both streams are alike in design, alike in chemical constitution, alike in process of development." The long-continued labor was not only that of the two astronomers we have named, but also that of the eighteenth and nineteenth century astronomers, Bradley and Groombridge, whose star atlases have furnished the means of comparison with star positions in the twentieth century. The astronomical discoveries of next century, perhaps incomparably greater than those of today, will depend similarly on the faithfulness and painful accuracy of the astronomers now living. It remains to add only that some of Kapteyn's earlier deductions regarding the movements of the stars have not

been confirmed (as is remarked by Mr. W. Bryant, in his "History of Astronomy", published in October), but that the hypothesis of the intersecting streams of the stellar universe has found wide acceptance.

The solar eclipse of January 14th has added little to astronomical knowledge because the points at which it could be profitably observed were too difficult of access to encourage expeditions, but several reports of it have come in. The New Year began with a legacy of sun-spot activity from the previous year. Another great group followed an extensive Northern group, and January ended with a larger extent of spotted area than when it began. February opened with seven groups, bequeathed from January, and from the 4th to the 11th-12th there were four great groups separately visible to the naked eye. There was another group on February 19th, March showed a falling off from the great activity of January and February, and an epoch of recovered solar activity, which had begun in November, 1906, may be said to have ended in this month. There were in March, numerous groups during the first four or five days, and there were six returns of other spots. In April the Sun was on no day free from spots, and there were three groups, inherited from March on the Northern Hemisphere. May was freer than April, as April had been freer than March, but two returning groups of spots were large enough to be visible with the naked eye. June's record was practically the history of a single group, which was, however, one of the finest groups of the contemporary maximum. It consisted of a straight and almost continuous stream made up of three very large spots, nearly equal in size, and close to each other, followed by a multitude of small attendants. The leader was the best defined, and was nearly circular. The last was barred by bright bridges. In July the area of sun-spots greatly decreased, though the June spot returned in much diminished magnificence. Mrs. E. W. Maunder followed up Mr. Maunder's researches on the magnetic influence of sun-spots and its causes, by a paper which appeared to suggest that the Earth itself exerted some reciprocal influence on sun-spots, and the data which led to this conclusion are still under consideration. Father Cortie, in an article in the *Astrophysical Journal*, discussing the variability in the light of Mira Ceti in relation to the evidence which it affords respecting the relative temperature of sun-spot vapors, came to the

conclusion that the temperature of sun-spots was lower than that of the solar photosphere.

Five comets were noted during the year. Giacobini's, noted by Giacobini, at Nice on March 9th, as of about the 11th magnitude; Grigg's, noted by Mr. John Grigg, of Thoms, New Zealand, on April 9th; another comet noted by Giacobini, as about the 13th magnitude, on June 1st; Daniel's comet, the most important of the year, which was first seen by Professor Daniel, of Princeton Observatory, U. S. A., on June 10th, and which was nearest to the Earth on August 1st, and brightest on August 21st; and Mellish's comet, discovered by Mrs. Mellish, on October 13th. Mellish's comet had several points of interest, approaching within twenty million miles of the Earth on November 11th, and being then visible in small telescopes.

Mars occupied the post of observational honor during 1907 though the opportunities of examining the Great Red Spot of Jupiter, the rings of Saturn, and the transit of Mercury were of great astronomical interest. A beaded appearance of Saturn's rings was remarked. As usual, Mars was the arena of controversy as to the nature and implications of its canals. Professor Simon Newcomb wrote an elaborate article to show that if all the 380 canals which have been charted on Mars were real, they would occupy a disproportionately large portion of the surface of Mars. He also made some interesting mathematical calculations as to the width which a Martian canal would have to be in order to be visible to observers with terrestrial telescopes, and suggested new tests of observation.

Professor Lowell, in an answer in the *Astrophysical Journal* to Professor S. Newcomb's criticisms, contended that the Martian canals needed a width of only fifteen miles for visibility, and that in the aggregate they need occupy, therefore, only one-tenth the planet's area.

Professor Lowell supplemented his rejoinder by the publication of the report of the expedition which was sent out during the year at his expense to Alianza, near Iquique, in Northern Chili, where it was believed that better conditions of vision would be secured. The expedition was equipped with a new 18-inch Clark refractor, and Professor Todd reported that with excellent conditions of seeing from June 18th to August 1st, many valuable photographs were obtained, which showed as many as twenty canals in one photograph. Numerous "double

canals" were also photographed, including Euphrates, Thoth, Eumenthes, Gihon, Astabour, Phison, and Nilokeras. Apart from this aspect of Mars, Professor Lowell, in addition to an interesting popular work on the planet, published an essay on the climate of Mars, in which he demonstrated with considerable plausibility that the temperature was not too low to support animal life. Among other papers and essays published during the year, which claim attention, were those of W. W. Coblenz and F. W. Very, on the temperature of the Moon (—225 C.); some new spectroheliograph work by Professor Hale, in the direction of solar photography with sun-spot lines; J. J. Lunt, on the presence of tin in stellar atmospheres; W. L. Elkin of Yale, on stellar parallaxes of ten stars of the 1st magnitude in the northern sky. We may also note the extension of Solon I. Bailey's catalogue, now including 1,173 stars in all, and a paper by E. Strongren and V. Heinrich, on the 2nd and 3rd Asteroids near Jupiter.

Professor Trowbridge, on a consideration of the reputed instances of the so-called meteor trains, came to the conclusion that the phosphorescence was dependent on the gas pressure of the strata where incandescence takes place. Professor Trowbridge also wrote an interesting essay on the character of "ball lightning."

Professor Seeliger having called attention to the absence on the photographs taken at the last eclipse of any indication of the existence of an intra-Mercurial planet, concludes that the mass of meteorites and meteoric dust in the solar system is sufficient to account for some unexplained planetary perturbations.

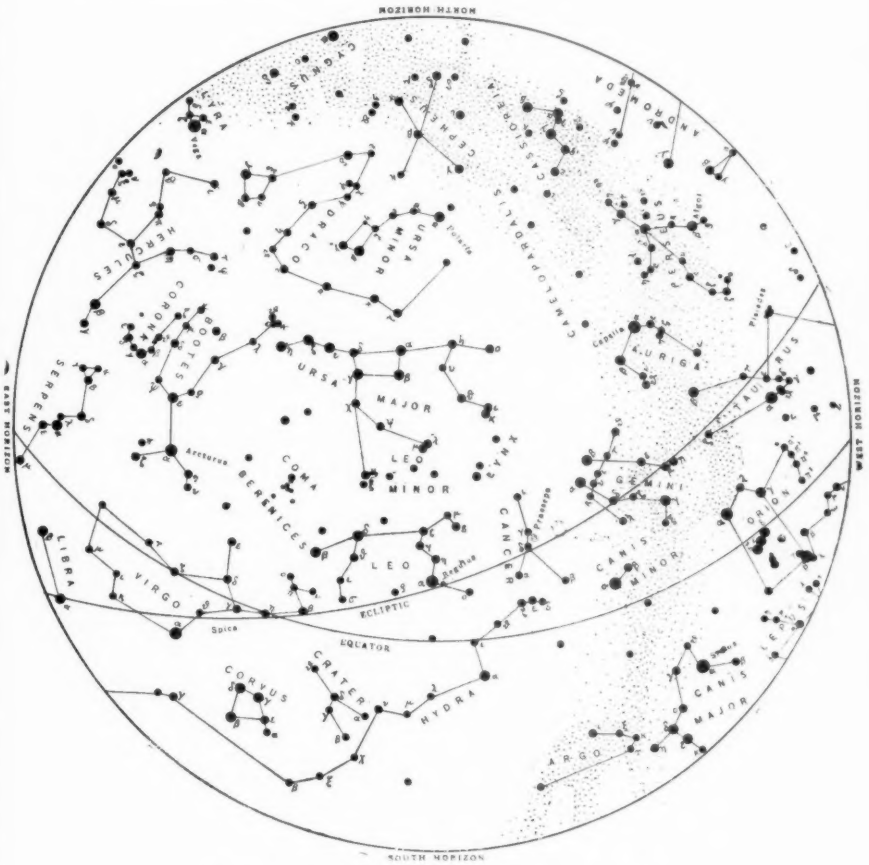
We may note also Professor Barnard's examination of a new theory on the cause of lanes and striations of blackness among the stars; Professor Pickering's investigations of the volcanoes of Hawaii, and his deductions as to the methods of formation of the craters of the Moon; and another paper by the same author, in which he suggested that the Moon before it was torn away from the Earth was in touch with the space now occupied by the South Pacific Ocean. Professor Poynting's suggestion, that Saturn's rings may represent the capture of a comet or cometary trains; and Professor Simon Newcomb's investigations of the irregularities of the movement of the Moon were of first-class importance.

SCIENCE YEAR BOOK 1908.

PLANET NOTES FOR APRIL 1908.

H. C. WILSON.

Mercury will be morning star during April but will be invisible to the naked eye except on the first three or four days. Mercury and Saturn will be in conjunction on April 14, Mercury being 28′ south of Saturn at 3 P. M., Central Standard Time.



THE CONSTELLATIONS AT 9:00 P. M., APRIL 1, 1908.

Venus during February has been very brilliant in the western sky in the early evening, and will increase rapidly in brightness during March and April. The phase of the planet will be slightly gibbous at the first of the month but will decrease to a little less than half full during the month. Venus and Mars

will be in conjunction on April 4 at 9 A. M., Central Standard Time, the former being then 1° 37′ north of the latter. Venus will be at greatest elongation, east from the Sun 45° 37′ on April 26. The planet will then be over 26° north of the equator, so that the position will be most favorable for the study of the surface markings. Little is known of the surface of this most brilliant of all the planets which seems to be enveloped in almost perpetual clouds, so that only the vaguest of markings can be detected. The present opportunity for study is one that should not be neglected by those who have the best of telescopes at their disposal and suitable atmospheric conditions.

Mars is way past the best position for observation for this year but may still be seen in the early evening. Its course for this month lies through Taurus. The conjunction with Venus has been mentioned in the preceding paragraph.

Jupiter vies with Venus in brilliancy on these clear winter nights but cannot equal his fair neighbor. Jupiter is nearly overhead at 8 P. M., while Venus is then well down toward the west Jupiter will be stationary on March 30, having finished his retrograde motion, and during the spring and summer will move eastward through Cancer into Leo. The planet will be at quadrature, 90° east from the Sun, April 24.

Saturn having just passed conjunction with the Sun is not in position for observation during April.

Uranus will be at quadrature 90° west from the Sun, April 6 and will be stationary in right ascension in Sagittarius April 21.

Neptune will be at quadrature, 90° east from the Sun, April 1 and may be found with the aid of a good telescope in the constellation Gemini in the early evening. Its position April 1 will be in right ascension $6^h\ 52^m\ 11^s$, declination north 22° 6′.

Occultations visible at Washington.

Date 1908	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration h m
Apr. 5	*l* Tauri	5.2	9 25	129	10 10	224	0 45
6	141 Tauri	6.3	9 54	34	10 27	332	0 33
8	B A.C. 2544	6.3	7 26	64	8 36	320	1 10
9	39 Cancri	6.5	11 34	157	12 20	241	0 46
9	40 Cancri	6.5	11 44	168	12 19	231	0 35
13	ρ Virginis	4.2	6 46	110	8 4	306	1 18
23	27 Capricorni	6.1	17 6	112	18 1	208	0 55
24	29 Aquarii	6.5	14 18	80	15 20	256	1 2

Phenomena of Jupiter's Satellites.

Central Standard Time, reckoning from noon.

	h	m					h	m			
Apr. 1	8	18	II	Sh.	Eg.	Apr. 6	9	27	III	Ec.	Re.
	8	42	I	Tr.	In.		11	8	II	Oc.	Dis.
	9	53	I	Sh.	In.	8	7	59	II	Sh.	In
	11	2	I	Tr	Eg.		8	24	II	Tr.	Eg.
	12	14	I	Sh	Eg.		10	34	I	Tr.	In.
2	9	22	I	Ec	Re.		10	55	II	Sh.	Eg
	11	7	III	Tr.	In.		11	48	I	Sh.	In
3	6	15	IV	Oc.	Dis.		12	54	I	Tr.	Eg.
	6	42	I	Sh.	Eg.	9	11	18	I	Ec	Re
	11	2	IV	Oc.	Re.	10	6	17	I	Sh	In

Phenomena of Jupiter's Satellites.—Continued.

	h	m			
Apr. 10	7	22	I	Tr.	Eg.
	8	37	I	Sh.	Eg.
12	6	58	IV	Sh.	Eg.
13	8	24	III	Oc.	Re.
	9	53	III	Ec.	Dis.
15	8	1	II	Tr.	In.
	10	37	II	Sh.	In.
	10	57	II	Tr.	Eg.
	12	27	I	Tr.	In.
16	9	38	I	Oc.	Dis.
17	6	55	I	Tr.	In.
	8	12	I	Sh.	In.
	8	19	II	Ec.	Re.
	9	15	I	Tr.	Eg.
	10	32	I	Sh.	Eg.

	h	m			
Apr. 18	7	42	I	Ec.	Re.
20	8	38	III	Oc.	Dis.
	11	52	IV	Ec.	Dis.
	12	19	III	Oc.	Re.
22	10	34	II	Tr.	In.
24	7	39	III	Sh.	Eg.
	8	49	I	Tr.	In.
	10	6	I	Sh.	In.
	10	54	II	Ec.	Re.
	11	10	I	Tr.	Eg.
	12	27	I	Sh.	Eg.
25	9	37	I	Ec.	Re.
26	6	56	I	Sh.	Eg.
28	8	10	IV	Tr.	In.

Note.—In., denotes ingress; Eg., denotes egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite: Sh., transit of the shadow.

COMET NOTES.

Ephemeris of Encke's Comet.

[Continued from page 113.]

1908	α app. h	m	s	δ app. °	′	log r	log Δ	Aber. Time m	s
April 1	1	43	59	+17	2.2	9.8884	0.2139	13	36
2		46	27	17	18.0	8782	2090		27
3		50	59	17	33.3	8677	2041		17
4		54	36	17	49.0	8568	1989	13	8
5	1	58	18	18	5.2	8456	1936	12	59
6	2	2	1	18	21.2	8341	1882		49
7		5	52	18	35.4	8222	1826		39
8		9	49	18	49.3	8100	1767		28
9		13	50	19	3.7	7975	1705		18
10		17	56	19	18.0	7845	1641	12	7
11		22	7	19	31.8	7711	1577	11	57
12		26	24	19	45.2	7573	1508		46
13		30	47	19	58.1	7432	1436		34
14		35	15	20	10.4	7288	1361		22
15		39	48	20	21.5	7139	1284	11	10
16		44	25	20	32.1	6987	1204	10	58
17		49	6	20	41.8	6833	1119		45
18		53	53	20	50.5	6675	1029		32
19	2	58	46	20	57.9	6516	0935		18
20	3	3	41	21	3.7	6358	0837	10	5
21		8	33	21	7.5	6201	0735	9	51
22		13	24	21	9.2	6047	0628		36
23		18	16	21	8.8	5899	0514		21
24		23	3	21	6.1	5759	0393	9	6
25		27	42	21	0.4	5631	0266	8	50
26		32	14	20	51.8	5517	0.0133		34
27		36	31	20	40.1	5423	9.9994		18
28		40	32	20	24.2	5350	9850	8	2
29		44	12	20	4.7	5304	9699	7	45
30	3	47	28	+19	41.4	9.5284	9.9543	7	29

VARIABLE STARS.

The Variable 136.1907 Andromedæ.—This variable appears to have a period of about 35 days.

In *A.N.* 4229 Mr. A. A. Nijland of Utrecht gives the following ephemerides of minima in the first part of 1908:

Period 34^d.79		Period 34^d.95		
1908 Jan. 29	7^h	1908 Jan. 29	11^h	Gr. M. T.
Mar. 4	2	Mar. 4	10	
Apr. 7	21	Apr. 8	9	
May 12	16	May 13	7	

Mr. Nijland gives the normal brightness as 10^m.7 (0^m.5 fainter than BD 42°29) and the minimum 12^m.2 or 0^m.2 fainter than a star which is 1′.3 north of the variable.

New Variable 182.1907 Draconis.—In the study of his observations of RW Draconis Dr. Hartwig finds that one of the comparison stars used is a long period variable. The star is missing from the Bonn DM but in December 1907 had a magnitude of 8.7. Its place is

	h	m	s	°	′	″
1855	16	32	59.15	+ 57	53	48.5
1900	16	33	47.59	+ 57	48	15.4

RW Tauri.—In *A. N.* 4229 Professor E. Hartwig gives the following elements of this antalgol variable, which completely satisfy his observations on December 17, 1907.

$$\text{Max.} = 2417407.27917 + 0^d.442938\ E.$$

Approximate Elements of Seven Variable Stars.—In *A. N.* 4223 Mr. Sigurd Enebo of Dombaas, Norway, gives the following approximate elements of seven of the variable stars discovered in 1907.

					Mag.
65.1907 Cassiop.	Max.	=1907 Aug. 20	21^h Gr. M.T.	+5^h 13^m E	9.0 — 9.7
		=2417808.88	"	+5^d.54 E	
68.1907 Persei	Min.	=1907 Oct. 8	7^h "	+2^d 15^h 31^m E	9.1—<10.5
		=2417857.29	"	+2^d.648 E	
132.1907 Lacertae	Max.	=1907 Sept. 4	9^h "	+10^d 17^h E	8.2 — 9.0
		=2417823.38	"	+10^h.7 E	
133.1907 Lacertae	Max.	=1907 Sept. 17	8^h "	+6^d 12^h E	8.5 — 9.2
		=2417836.33	"	+6^d.5 E	
39.1907 Camelop.	Max.	=1907 Oct. 8 (2417857)		+16.^{d} E	8.2 — 9.4
43.1907 Draconis	Max.	=1907 Sept. 26	6^h 30^m "	+0^d 9^h 33^m E	8.9 — 9.6
		=2417845.27	"	+0^d.3978 E	
73.1907 Persei	Max.	=1907 Sept. 11 (2417830)		+11^d.2 E	8.8 — 9.6

(65.1907 = SW Cassiop.)

Two New Variable Stars 1 and 2.1908.—These were discovered by Mr. Sigurd Enebo of Dombaas, Norway, and are announced in *A. N.* 4229. Their positions for 1855 are

	h	m	s	°	′	″
1.1908 Geminorum	α = 6	31	14.9	δ = + 31	19.0	
2.1908 Persei	4	00	53.06	41	49	27.9

The first is BD + 31°1380 (9.^{m}2). From March to December 1906 it was invisible with a telescope of 70^{mm} aperture. On Dec. 24 1906 it was about 9.5 magnitude. On April 12, 1907 in was again invisible with a telescope of 108^{mm} aperture and has not been visible since that time. The period is

long, possibly about 20 months. The next maximum will be expected about August 1908.

The second star is BD + 41°824 (8^m.5) and varies between 8.4 and 9.6 magnitude. The period is about 160 days, approximate elements being:

Max = 1905 Dec. 9 (2417189) + 160^d E.

The color of the star is yellowish red.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei		RT Persei		RW Tauri		RW Monoc.		R Canis Maj.	
d	h	d	h	d	h	d	h	d	h
Apr. 1	20	Apr. 1	5	Apr. 16	11	Apr. 16	16	Apr. 9	5
4	8	2	2	19	6	18	14	10	8
6	20	2	22	22	0	20	12	11	11
9	8	3	19	24	19	22	10	12	14
11	19	4	15	27	13	24	7	13	18
14	7	5	11	30	7	26	5	14	21
16	19	6	8	RV Persei		28	3	16	0
19	7	7	4	Apr. 1	13	30	1	17	3
21	19	8	1	3	12	RU Monoc.		18	7
24	7	8	21	5	11	Apr. 1	1	19	10
26	18	9	17	7	11	1	23	20	13
29	6	10	14	9	10	2	20	21	16
RZ Cassiop.		11	10	11	10	3	18	22	20
Apr. 2	8	12	6	13	9	4	15	23	23
3	13	13	3	15	8	5	13	25	2
4	17	13	23	17	8	6	10	26	6
5	22	14	20	19	7	7	8	27	9
7	3	15	16	21	6	8	5	28	12
8	7	16	12	23	6	9	3	29	15
9	12	17	9	25	5	10	0	30	19
10	17	18	5	27	4	10	22	Y Camelop.	
11	21	19	2	29	4	11	19	Apr. 3	4
13	2	19	22	RW Persei		12	17	6	11
14	7	20	18	Apr. 5	6	13	14	9	19
15	11	21	15	18	11	14	12	13	2
16	16	22	11	RS Cephei		15	9	16	10
17	21	23	8	Apr. 2	17	16	7	19	17
19	2	24	4	15	3	17	4	23	0
20	6	25	0	27	13	18	2	26	8
21	11	25	21	RW Geminorum		18	23	29	15
22	15	26	17	Apr. 1	7	19	21	RR Puppis	
23	20	27	13	4	4	20	18	Apr. 5	10
25	1	28	10	7	1	21	16	11	21
26	6	29	6	9	22	22	13	18	7
27	10	30	3	12	19	23	11	24	17
28	15	30	23	15	15	24	8	V Puppis	
29	20	λ Tauri		18	12	25	6	Apr. 1	10
31	0	Apr. 4	2	21	9	24	3	2	21
RX Cephei		8	1	24	6	27	1	4	8
Apr. 28	13	12	0	27	2	27	22	5	19
Algol		15	22	29	23	28	20	7	6
Apr. 3	1	19	21	RW Monoc.		29	17	8	17
5	22	23	20	Apr. 1	10	30	15	10	4
8	19	27	19	3	8	R Canis Maj.		11	15
11	16	RW Tauri		5	6	Apr. 1	6	13	2
14	12	Apr. 2	15	7	3	2	9	14	12
17	9	5	9	9	1	3	12	15	23
20	6	8	4	10	23	4	15	17	10
23	3	10	22	12	21	5	19	18	21
26	0	13	17	14	18	6	22	20	8
28	20					8	1		

Minima of Variable Stars of the Algol Type.—Continued.

V Puppis

	d	h
Apr.	21	19
	23	6
	24	17
	26	4
	27	15
	29	2
	30	12

X Carinæ

	d	h
Apr.	1	0
	2	2
	3	4
	4	6
	5	8
	6	10
	7	12
	8	14
	9	16
	10	18
	11	20
	12	22
	14	0
	15	2
	16	4
	17	6
	18	8
	19	10
	20	12
	21	14
	22	16
	23	18
	24	20
	25	22
	27	0
	28	2
	29	4
	30	6

S Cancri

	d	h
Apr.	2	22
	12	10
	21	22

S Velorum

	d	h
Apr.	3	10
	9	8
	15	7
	21	5
	27	4

RR Velorum

	d	h
Apr.	1	1
	2	21
	4	18
	6	14
	8	11
	10	7
	12	4
	14	0
	15	21
	17	17
	19	14
	21	10
	23	7

RR Velorum

	d	h
Apr.	25	3
	27	0
	28	20
	30	17

Z Draconis

	d	h
Apr.	1	0
	2	8
	3	17
	5	1
	6	10
	7	18
	9	3
	10	12
	11	20
	13	5
	14	13
	15	22
	17	6
	18	15
	20	0
	21	8
	22	17
	24	1
	25	10
	26	19
	28	3
	29	12
	30	20

RZ Centauri

	d	h
Apr.	1	19
	2	17
	3	16
	4	14
	5	13
	6	11
	7	10
	8	8
	9	7
	10	5
	11	4
	12	2
	13	1
	14	22
	15	20
	16	19
	17	17
	18	16
	19	14
	20	13
	21	11
	22	10
	23	8
	24	7
	25	5
	26	4
	27	2
	28	1
	28	23
	29	22
	30	20

SS Centauri

	d	h
Apr.	1	20
	4	8
	6	19
	9	7
	11	18
	14	6
	16	17
	19	5
	21	16
	24	4
	26	15
	29	3

δ Libræ

	d	h
Apr.	2	18
	5	1
	7	9
	9	17
	12	1
	14	9
	16	17
	19	1
	21	8
	23	16
	26	0
	28	8
	30	16

U Coronæ

	d	h
Apr.	3	15
	7	3
	10	13
	14	0
	17	11
	20	22
	24	8
	27	19

R Aræ

	d	h
Apr.	2	9
	6	19
	11	5
	15	16
	20	2
	24	12
	28	22

U Ophiuchi

	d	h
Apr.	1	11
	2	7
	3	4
	4	0
	4	20
	5	16
	6	12
	7	8
	8	4
	9	0
	9	21
	10	17
	11	13
	12	9
	13	5
	14	1

U Ophiuchi

	d	h
Apr.	14	21
	15	17
	16	14
	17	10
	18	6
	19	2
	19	22
	20	18
	21	14
	22	10
	23	6
	24	3
	24	23
	25	19
	26	15
	27	11
	28	7
	29	3
	30	0
	30	20

Z Herculis

	d	h
Apr.	1	9
	3	6
	5	9
	7	6
	9	9
	11	6
	13	9
	15	6
	17	8
	19	5
	21	8
	23	5
	25	8
	27	5
	29	8

RS Sagittarii

	d	h
Apr.	1	1
	3	11
	5	21
	8	7
	10	17
	13	3
	15	13
	17	23
	20	9
	22	19
	25	5
	27	15
	30	0

V Serpentis

	d	h
Apr.	3	11
	6	22
	10	9
	13	20
	17	7
	20	18
	24	5
	27	15

RZ Draconis

	d	h
Period	13	5.2
Apr.	1	12
	2	15
	3	17
	4	20
	5	22
	7	1
	8	3
	9	6
	10	8
	11	10
	12	13
	13	15
	14	18
	15	20
	16	23
	18	1
	19	4
	20	6
	21	8
	22	11
	23	13
	24	16
	25	18
	26	21
	27	23
	29	2
	30	4

RX Herculis

	d	h
Apr.	1	21
	2	18
	3	15
	4	13
	5	10
	6	7
	7	5
	8	2
	8	23
	9	21
	10	18
	11	15
	12	13
	13	10
	14	8
	15	5
	16	2
	17	0
	17	21
	18	18
	19	16
	20	13
	21	10
	22	8
	23	5
	24	2
	25	0
	25	21
	26	18
	27	16
	28	13
	29	10

Minima of Variable Stars of the Algol Type.—Continued.

RX Herculis

	d	h
Apr.	30	8

SX Sagittarii

Apr.	1	12
	3	14
	5	16
	7	18
	9	20
	11	21
	13	23
	16	1
	18	3
	20	5
	22	7
	24	8
	26	10
	28	12
	30	14

RR Draconis

Apr.	2	13
	5	9
	8	5
	11	1
	13	21
	16	17
	19	13
	22	9
	25	5
	28	1
	30	21

U Scuti

Apr.	1	8
	2	7
	3	6
	4	4
	5	3

U Scuti

Apr.	6	2
	7	1
	8	0
	8	23
	9	22
	10	21
	11	20
	12	19
	13	18
	14	17
	15	15
	16	14
	17	13
	18	12
	19	11
	20	10
	21	9
	22	8
	23	7
	24	6
	25	5
	26	4
	27	3
	28	1
	29	0
	29	23
	30	22

RX Draconis

Apr.	2	15
	4	12
	6	10
	8	7
	10	5
	12	2
	13	23

RX Draconis

Apr.	15	21
	17	18
	19	16
	21	13
	23	11
	25	8
	27	6
	29	3

RV Lyræ

Apr.	1	13
	5	3
	8	18
	12	8
	15	22
	19	13
	23	3
	26	18
	30	18

U Sagittæ

Apr.	1	1
	4	10
	7	19
	11	4
	14	13
	17	22
	21	8
	24	17
	28	2

SY Cygni

Apr.	6	6
	12	7
	18	7
	24	7
	30	7

WW Cygni

Apr.	1	1
	4	8
	7	16
	10	23
	14	7
	17	15
	20	22
	24	6
	27	14
	30	21

SW Cygni

Apr.	1	20
	6	9
	10	23
	15	13
	20	3
	24	16
	29	6

VW Cygni

Apr.	2	17
	11	4
	19	14
	28	0

UW Cygni

Apr.	1	18
	5	4
	8	15
	12	2
	15	13
	19	0
	22	10
	25	21
	29	8

W Delphini

Apr.	2	12
	8	8
	12	3
	16	22
	22	18
	26	13

RR Delphini

Apr.	4	5
	8	20
	13	10
	18	0
	22	15
	27	5

VV Cygni

Apr.	2	5
	3	16
	5	4
	6	15
	8	3
	9	14
	11	2
	12	13
	14	1
	15	12
	17	0
	18	11
	19	22
	21	10
	22	21
	24	9
	25	20
	27	8
	28	19
	30	7

UZ Cygni

Apr.	28	4

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

	d	h
	(−5	19)
Apr.	7	7
	21	2

RX Aurigæ

	(−4	0)
Apr.	4	12
	16	3
	27	18

Y Aurigæ

	(−0	18)
Apr.	1	4
	5	1
	8	22
	12	18
	16	15
	20	11

Y Aurigæ

Apr.	24	8
	28	5

T Monoc.

	(−7	23)
Apr.	2	10
	29	10

W Geminorum

	(−2	22)
Apr.	7	17
	15	15
	23	13

ξ Geminorum

	(−5	0)
Apr.	10	18
	20	21

RU Camelop.

	d	h
	(−9	12)
Apr.	11	3
May	3	10

V Carinæ

	(−2	4)
Apr.	7	14
	14	6
	20	23
	27	16

T Velorum

	(−1	10)
Apr.	1	15
	6	6
	10	22
	15	13
	20	4

T Velorum

Apr.	24	20
	29	11

W Carinæ

	(−1	0)
Apr.	1	5
	5	13
	9	22
	14	7
	18	16
	23	1
	27	10

S Muscæ

	(−3	11)
Apr.	10	4
	19	20
	29	11

T Crucis

	d	h
	(−2	2)
Apr.	5	15
	12	8
	19	2
	25	19

R Crucis

	(−1	10)
Apr.	1	0
	6	20
	12	16
	18	12
	24	7
	30	3

S Crucis

	(−1	12)
Apr.	1	3

S Crucis

	d	h
Apr.	5	20
	10	12
	15	5
	19	22
	24	14
	29	7

W Virginis

(−8 5)

Apr.	13	0
	30	7

V Centauri

(−1 11)

Apr.	4	5
	9	17
	15	4
	20	16
	26	2

R Triang. Austr.

(−1 0)

Apr.	2	21
	6	6
	9	15
	13	0
	16	10
	19	19
	23	5
	26	14
	29	23

S Triang. Austr.

(−2 2)

Apr.	1	5
	7	13
	13	20
	20	4
	26	12

S Normæ

(−4 10)

Apr.	1	5
	10	23
	20	17
	30	11

RV Scorpii

(−1 10)

Apr.	6	23
	13	0
	19	2
	25	3

RV Ophiuchi

	d	h
	Minimum.	
Apr.	3	9
	7	1
	10	18
	14	10
	18	3
	21	19
	25	12
	29	4

X Sagittarii

(−2 22)

Apr.	3	0
	10	0
	17	1
	24	1

Y Ophiuchi

(−6 5)

Apr.	10	4
	27	7

W Sagittarii

(−3 0)

Apr.	6	16
	14	6
	21	20
	29	10

Y Sagittarii

(−2 2)

Apr.	6	11
	12	6
	18	0
	23	19
	29	14

U Sagittarii

(−2 23)

Apr.	5	17
	12	11
	19	5
	25	23

***β* Lyræ**

(−3 7)
(−3 2)

Apr.	8	4
	14	10
	21	2
	27	7

***κ* Pavonis**

	d	h
	(−1	7)
Apr.	6	18
	15	20
	24	22

U Aquilæ

(−2 4)

Apr.	5	1
	12	1
	19	2
	26	2

U Vulpeculæ

(−2 3)

Apr.	6	16
	14	16
	22	15
	30	15

SU Cygni

(−1 7)

Apr.	1	1
	4	22
	8	18
	12	14
	16	10
	20	7
	24	3
	27	23

X Vulpeculæ

(−2 1)

Apr.	7	3
	13	11
	19	18
	26	2

V Vulpeculae
Minimum

Apr.	4	9

X Cygni

(−6 19)

Apr.	7	13
	23	23

T Vulpeculae

(−1 10)

Apr.	1	1
	5	11
	9	21
	14	8
	18	18

T Vulpeculae

	d	h
Apr.	23	5
	27	15

WZ Cygni
Period 14h
Minimum

Apr.	1	1
	2	5
	3	9
	4	13
	5	17
	6	21
	8	1
	9	5
	10	9
	11	13
	12	17
	13	22
	15	2
	16	6
	17	10
	18	14
	19	18
	20	22
	22	2
	23	6
	24	10
	25	14
	26	18
	27	22
	29	2
	30	6

TX Cygni

Apr.	12	7
	27	1

VY Cygni

(−2 14)

Apr.	5	3
	12	23
	20	20
	28	16

VZ Cygni

(−2 12)
(−3 6)

Apr.	10	13
	15	13

VZ Cygni

	d	h
Apr.	20	6
	25	6
	30	0

***δ* Cephei**

(−1 10)

Apr.	2	4
	7	13
	12	22
	18	7
	23	16
	29	0

Y Lacertae

(−1 10)

Apr.	2	10
	6	18
	11	1
	15	9
	19	16
	24	0
	28	7

V Lacertae

(−0 17)

Apr.	5	5
	10	5
	15	4
	20	4
	25	4
	30	3

X Lacertae
Minimum

Apr.	6	10
	11	20
	17	7
	22	17
	28	4

RS Cassiop.

(−1 19)

Apr.	5	18
	12	1
	18	8
	24	15
	30	22

RY Cassiop.

(−7 10)

Apr.	2	10
	14	14
	26	17

Approximate Magnitudes of Variable Stars on Feb. 1, 1908.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900 h	m	Decl. 1900 °	′	Magn.
X Androm.	0	10.8	+46	27	<13.5	W Cassiop.	0	49.0	+58	1	10.5*d*
T Androm.		17.2	+26	26	7.8 *i*	RX Androm.		58.9	+40	46	12.8*d*
T Cassiop.		17.8	+55	14	11.0*d*	U Androm.	1	9.8	+40	11	<13.5
R Androm.		18.8	+38	1	13.8*d*	S Piscium		12.4	+ 8	24	11.2 *i*
S Ceti		19.0	− 9	53	8.2 *i*	S Cassiop.		12.3	+72	5	13.0 *i*
Y Cephei		31.3	+79	48	13.4*d*	U Piscium		17.7	+12	21	13.0 *i*
U Cassiop.		40.8	+47	43	11.0 *i*	R Piscium		25.5	+ 2	22	14.0
RW Androm.		41.9	+32	8	13.0 *i*	RU Androm.		32.8	+38	10	11.6*d*
V Androm.		44.6	+35	6	11.3 *i*	Y Androm.		33.7	+38	50	10.0*d*
RR Androm.		45.9	+33	50	<13	X Cassiop.		49.8	+58	46	10.5

Approximate Magnitudes of Variable Stars on Feb. 1, 1908—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
U Persei	1	53.0	+54	50	7.8 *i*	Y Draconis	9	31.1	+78	18	12.8 *i*
S Arietis		59.3	+12	3	13.6	R Leo. Min.		39.6	+34	58	9.0*d*
R Arietis	2	10.4	+24	35	7.8 *i*	R Leonis		42.2	+11	54	6.3 *i*
W Androm.		11.2	+43	50	<13.5	V Leonis		54.5	+21	44	<13
Z Cephei		12.8	+81	13	14.0	R Urs. Maj.	10	37.6	+69	18	11.2*d*
o Ceti		14.3	− 3	26	6.2*d*	T Urs. Maj.	12	31.8	+60	2	8.2*d*
S Persei		15.7	+58	8	8.5	RS Urs. Maj.		34.4	+59	2	10.0 *i*
R Ceti		20.9	− 0	38	12.8 *i*	S Urs. Maj.		39.6	+61	38	7.5 *i*
U Ceti		28.9	−13	35	8.0 *i*	U Urs. Min.	14	15.1	+67	15	11.0*d*
RR Cephei		30.4	+80	42	<13	S Bootis		19.5	+54	16	11.5 *i*
R Trianguli		31.0	+33	50	8 4 *i*	R Camelop.		25.1	+84	17	8.5 *i*
T Arietis		42.8	+17	6	9.4	R Bootis		32.8	+27	10	9.0*d*
W Persei		43.2	+56	34	9.5	S Urs. Min.	15	33.4	+78	58	11.3
U Arietis	3	5.5	+14	55	7.7 *i*	U Draconis	19	9.9	+67	7	<13
X Ceti		14.3	− 1	26	9.0 *i*	U Lyrae		16.6	+37	42	11.5*d*
Y Persei		20.9	+43	50	9.0	R Cygni		34.1	+49	58	13.6*d*
R Persei		23 7	+35	20	12.0 *i*	RT Cygni		40.8	+48	32	9.4d
Nov. Per. 2		24.4	+43	34	13.3*d*	TU Cygni		43.3	+48	49	<13.5
T Tauri	4	16.2	+19	18	11.4*d*	χ Cygni		46.7	+32	40	11.0 *i*
R Tauri		22.8	+ 9	56	13.5*d*	Z Cygni		58.6	+49	46	8.0 *i*
W Tauri		22.2	+15	49	9.0*d*	S Cygni	20	3.4	+57	42	10.0 *i*
S Tauri		23.7	+ 9	44	11.0	RS Cygni		9.8	+38	28	8.3 *i*
T Camelop.		30.4	+65	57	8.2 *i*	WX Cygni		14.8	+37	8	10.0 *i*
RX Tauri		32.8	+ 8	9	14.0	U Cygni		16.5	+47	35	7.6 *i*
X Camelop.		32.6	+74	56	8.0	RW Cygni		25.2	+39	39	8.6*d*
V Tauri		46.2	+17	22	9.5 *i*	Z Delphini		28.1	+17	7	7.8 *i*
R Orionis		53.6	+ 7	59	10.0*d*	ST Cygni		29.9	+54	38	13.4
V Orionis	5	0.8	+ 3	58	11.8*d*	Y Delphini		36.9	+11	31	12.6*d*
T Leporis		0.6	−22	2	11.2*d*	S Delphini		38.5	+16	44	11.4*d*
R Aurigae		9.2	+53	28	9.5*d*	V Cygni		38.1	+47	47	12.6*d*
S Aurigae		20.5	+34	4	10.4	T Delphini		40.7	+16	2	12.5 *i*
W Aurigae		20.1	+36	49	9.0 *i*	V Delphini		43.2	+18	58	<13.5
S Orionis		24.1	− 4	46	11.4*d*	X Delphini		50.3	+17	16	10.5*d*
T Orionis		30.9	− 5	32	9.5	R Vulpeculae		59.9	+23	26	8.0 *i*
S Camelop.		30.2	+68	45	10.0	TW Cygni	21	1.8	+29	0	10.6 *i*
U Aurigae		35.6	+31	59	11.5*d*	X Cephei		3.6	+82	40	<13.5
U Orionis		49.9	+20	10	11.0 *i*	T Cephei		8.2	+68	5	10.2*d*
V Camelop.		49.4	+74	30	<13	S Cephei		36.5	+78	10	8.5 *i*
Z Aurigæ		53.6	+53	18	10.0	RU Cygni		37.3	+53	52	8.0 *i*
V Monoc.	6	17.7	− 2	9	11.0*d*	RR Pegasi		40.0	+24	33	12.7*d*
R Monoc.		33.7	+ 8	49	11.5 *i*	V Pegasi		56.0	+ 5	38	10.5*d*
X Gemin.		40.7	+30	23	11.5	RT Pegasi		59.8	+34	38	9.6 *i*
W Monoc.		47.5	− 7	2	9.5 *i*	T Pegasi	22	4.0	+12	3	13.5*d*
Y Monoc.		51.3	+11	22	<13	Y Pegasi		6.8	+13	52	13.5
X Monoc.		52.4	− 8	56	7.5	RS Pegasi		7.4	+14	4	8.0 *i*
R Lyncis		53.0	+55	28	9.8*d*	RV Pegasi		21.0	+29	58	13.0*d*
R Gemin.	7	1.3	+22	52	13.0*d*	S Lacertae		24.6	+39	48	12.7*d*
V Can. Min.		1.5	+ 9	2	13.5*d*	R Lacertae		38.8	+41	51	13.8*d*
R Can. Min.		3.2	+10	11	8.8 *i*	RW Pegasi		59.2	+14	46	7.8*d*
RR Monoc.		12.4	+ 1	17	12.4*d*	R Pegasi	23	1.6	+10	0	12.4*d*
V Gemin.		17.6	+13	17	8.8	V Cassiop.		7.4	+59	8	13.2*d*
S Can Min.		27.3	+ 8	32	12.0*d*	W Pegasi		14.8	+25	44	9.6*d*
T Can. Min.		28.4	+11	58	13.0*d*	S Pegasi		15.5	+ 8	22	13.2*d*
U Can. Min.		35.9	+ 8	37	9.5 *i*	Z Androm.		28.8	+48	16	11.0
S Gemin.		37.0	+23	41	<13.5	— Androm.		33.8	+35	13	9.0 *i*
T Gemin.		43.3	+23	59	8.8 *i*	Z Cassiop.		39.7	+56	2	13.8*d*
U Puppis		56.1	−12	34	12.2*d*	RR Cassiop.		50.7	+53	8	<13
R Cancri	8	11.0	+12	2	10.0*d*	V Ceti		52.8	− 9	31	8.5 *i*
V Cancri		16.0	+17	36	8.0	R Cassiop.		53.3	+50	50	10.8*d*
RT Hydrae		24.7	− 5	59	8.4	Z Pegasi		55.0	+25	21	8.0 *i*
S Hydrae		48.4	+ 3	27	9.2 *i*	W Ceti		57.0	−15	14	10.0*d*
T Hydrae		50.8	− 8	46	8.4 *i*	Y Cassiop.		58.2	+55	7	<14
W Cancri	9	4.0	+25	39	11.5*d*						

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Whitin, Mt. Holyoke, and Harvard Observatories.

GENERAL NOTES.

Transit of Mercury. In answer to Professor Snyder's request I can give from a layman's standpoint the experience we had.

Our observation was with an almost perfect atmosphere and with but one or two small passing clouds. The half hour preceding the third contact was as nearly perfect as I have ever seen, there being a minimum of "boiling."

Between third and fourth contact a very small cloud passed over but gave no trouble but rather acted as a rest for the eye.

During the transit the image of Mercury appeared raised from the Sun so that Mrs. Merritt expressed it as looking as though a card could be passed between it and the Sun.

To observe the third and fourth contacts I projected the image using an undeveloped photograph plate as this gives me the best surface I have ever found upon which to throw projections. Just after third contact our view was interrupted by the cloud referred to but only for a few seconds and on the re-appearance we unmistakably saw the whole disk of Mercury and continued to see it till three or four seconds after the fourth contact.

The instrument used was a 4″ Alvan Clark Equatorial.

M. G. MERRITT.

Rome, New York.
January 20, 1908.

Resume of Sun-Spot Observations, 1907.

Month	No. of Obs.	N. of Equator No. Groups	Av. Lat. °	S. of Equator No. Groups	Av. Lat. °	Av. No. at each Obs.	New Groups
January	12	14	+ 9.6	7	−11.2	4.3	21
February	17	11	10.0	9	12.7	6.0	17
March	16	8	10.2	14	12.6	4.8	17
April	9	4	9.8	4	18.9	2.0	8
May	13	6	6.6	6	13.0	2.7	12
June	12	2	10.2	4	17.5	2.2	5
October	26	6	5.8	11	16.4	3.2	17
November	16	6	7.7	5	13.0	3.0	9
December	7	3	8.1	7	15.6	4.4	10
Total	128	60		67			116

Average number at each observation 3.61
Average latitude of spots north of equator +9°.0
Average latitude of spots south of equator −14°.6

The Sun was observed only once when no spots were seen, November 29th.

In the résumé a group appearing upon the eastern limb was counted as "new", even though the same area had been disturbed when upon the western limb a few days earlier.

Observations were made with the eight-inch equatorial. The image of the Sun was projected upon Thomson's Disks, for which approximate latitude

and distance from the center can be read at once for each group. The record from January to June was made by Miss Elizabeth Schindler, that for October to December by Miss Anna Oathout.

ANNE SEWELL YOUNG.

Mount Holyoke College Observatory.

Richard Hinckley Allen. At 4:00 A. M., Tuesday January 14, at Northampton, Mass., passed from this life Mr. Richard Hinckley Allen of Chatham, N. J. Mr. Allen was the author of "*Star Names aud Their Meanings*,"—a work of wide research and of classical value in astronomical literature, with which most of the readers of POPULAR ASTRONOMY must be familiar. He was also a member of the Astronomical Society of the Pacific and the American Association for the Advancement of Science.

A brief sketch of his career as man of business and as an author appeared about a year ago in POPULAR ASTRONOMY (Vol 14 Page 592) accompanied by his portrait.

Although Mr. Allen had not enjoyed excellent health during recent years, yet he was actively engaged in a careful revision of his book, ever having the greatest regard for absolute accuracy in every portion of its contents. On Thursday preceding his death, while suffering from a severe attack of the grippe, he left his New Jersey home to attend the funeral of his sister in Massachusetts. The exposure induced pneumonia to which he succumbed. He is survived by his widow, who was Miss Mary C. Wallace of Chatham, N. J., and a brother Rev. Arthur H. Allen and a niece Miss Agnes G. C. Allen. Interment was made in Mount Pleasant Cemetary.

By all those who were acquainted with Mr. Allen, he was considered a most highly respected gentleman; by his friends, affectionately loved for his kindly courteous manner and whole-souled cordiality. He was a Christian who could see in the stars whose names he had enrolled and explained, the work of a Divine Artificer, and his activity was evidenced by his election to an eldership and trusteeship of the Presbyterian Church at Chatham, and in that church on January 26th was held a special Memorial Service in his honor.

H. S. D.

A Reply to Francis Rust's Paper (January 1908.) The January number of this Journal contains an article by Mr. Francis Rust, which calls for a reply and criticism. The author presents what he calls "a new method to compute a planet's anomaly and radius vector" but fails to recognize that his equation (6) is nothing but Kepler's equation. That this is indeed the outcome of his rather uselessly laborious mode of integrating $r^2 \frac{d\theta}{dt} = c$ will be evident from his equation (7) which defines his auxiliary angle χ. This equation (7) is as follows

$$\text{tang } \chi = \sqrt{\frac{1-e}{1+e}} \text{ tg } \frac{\theta}{2},$$

but everybody knows that the eccentric anomaly u is defined by

$$\text{tg } u/2 = \sqrt{\frac{1-e}{1+e}} \text{ tg } \frac{\theta}{2}$$

$$\therefore \quad u = 2\chi \qquad \ldots (a)$$

Equation (6) reads as follows:

$$(6) \qquad S = \chi \cos \kappa - \frac{1}{4} \sin 2\kappa \sin 2\chi$$

where $\sin \kappa = e$, by making use of (a) we obtain

$$S = \frac{u}{2}\sqrt{1-e^2} - \frac{1}{2} e\sqrt{1-e^2} \sin u \qquad \text{or}$$

$$\frac{2S}{\sqrt{1-e^2}} = u - e \sin u.$$

We would have Kepler's equation if we were to express the left side as a linear function of t, but this our author does not clearly indicate although he actually carries it out in his example. He simply looks upon the right side of (6) as an expression for the area S between $\theta = 0$ and $\theta = \theta$. Then he proposes to construct a table for S with the argument θ. This done he solves the problem: given a time t to find the angle θ, by first computing S as a linear function of time and then interpolates the value of θ by his table. It is hardly necessary to point out that the astronomer in solving the same problem turns too to Kepler's equation to find the value of the eccentric anomaly and then obtains by $\text{tg } \theta/2 = \sqrt{\frac{1-e}{1+e}}\ \text{tg } u/2$ the value of θ. To construct a table in the way Mr. Rust proposes would hardly repay the great labor spent in computing it, since even for the orbit of the Earth the eccentricity is constantly undergoing changes. To take account of these an additional table for $\frac{d\theta}{de}$ would be necessary. Astronomers since the days of Kepler have not been entirely unsuccessful in devising modes of computation for this ever recurring and fundamental problem of Astronomy. A careful perusal of a textbook on theoretical astronomy and a study of astronomical tables like those of Bauschinger will reveal to the reader most valuable stores of information of which he should eagerly avail himself before he attempts an improvement in this course of study. The knowledge so gained will enable the reader to use astronomical ephemerides intelligently without which some astronomical data could easily appear "not harmonious to the layman" (see remark on page 42 of this journal).

KURT LAVES.

Chicago, Ill.
February 1908.

Ephemeris for Physical Observations of the Sun.

1908	Greenwich Mean Noon. P.	D.	L.	1908	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′		° ′	° ′	° ′
Jan. 1	+ 2 23	−3 5	0 22	Feb.20	−18 55	−7 2	61 59
6	− 0 3	3 39	294 31	25	20 24	7 10	356 8
11	2 28	4 11	228 40	Mar.1	21 44	7 14	290 17
16	4 51	4 42	162 50	6	22 55	7 15	224 25
21	7 10	5 10	97 0	11	23 56	7 13	158 31
26	9 25	5 36	31 10	16	24 47	7 7	92 37
31	11 33	5 59	325 20	21	25 27	6 58	26 42
Feb. 5	13 35	6 20	259 31	26	25 58	6 46	320 46
10	15 30	6 37	193 41	31	26 17	6 31	254 49
15	−17 16	−6 51	127 50	Apr. 5	−26 26	−9 13	188 50

1908	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′
Apr. 10	−26 24	−5 53	122 50
15	26 11	5 30	56 50
20	25 47	5 4	350 47
25	25 11	4 37	284 44
30	24 25	4 7	218 40
May 5	23 28	3 37	152 34
10	22 20	3 4	86 28
15	21 2	2 30	20 20
20	19 34	1 55	314 11
25	17 57	1 20	348 2
30	16 11	0 44	181 52
June 4	14 18	−0 8	115 43
9	12 18	+0 28	49 32
14	10 12	1 4	343 21
19	8 2	1 40	277 10
24	5 48	2 16	210 59
29	3 32	2 48	144 48
July 4	−1 15	3 21	78 37
9	+1 2	3 52	12 26
14	3 17	4 22	306 17
18	5 30	4 50	240 7
24	7 39	5 16	173 58
29	9 46	5 40	107 50
Aug. 3	11 45	6 1	41 42
8	13 40	6 20	335 35
13	15 28	6 37	269 29
18	+17 10	+6 50	203 24

1908	Greenwich Mean Noon. P.	D.	L.
	° ′	° ′	° ′
Aug. 23	+18 44	+7 1	137 20
28	20 11	7 8	71 16
Sept. 2	21 30	7 13	5 13
7	22 40	7 15	299 11
12	23 42	7 13	233 10
17	24 34	7 9	167 9
22	25 17	7 1	101 10
27	25 50	6 50	35 10
Oct. 2	26 13	6 36	329 12
7	26 25	6 19	263 14
12	26 26	5 59	197 16
17	26 16	5 37	141 19
22	25 54	5 11	65 22
27	25 21	4 44	359 26
Nov. 1	24 36	4 14	293 30
6	23 39	3 43	227 34
11	23 31	3 9	161 40
16	21 10	2 34	95 44
21	19 39	1 58	29 50
26	17 57	1 20	323 56
Dec. 1	16 5	0 42	258 2
6	14 4	+0 4	192 9
11	11 56	−0 35	126 16
16	9 40	1 13	60 23
21	7 20	1 50	354 32
26	4 56	2 28	288 40
31	+2 31	−3 3	222 49

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′ and the longitude of the ascending node for 1908.0 to be 74° 28′.6. In computing L (the heliographic longitude of the center of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854.0 has been taken as the zero meridian.

COMPANION TO THE OBSERVATORY, No. 391.

Carnegie Solar Observatory on Mount Wilson California. In a recent lecture, Professor George E. Hale gave a description of the new tower telescope and the tests already made with it.

This telescope consists of a vertical steel tower, sixty-five feet in height, on the summit of which are mounted two plane mirrors, which receive the rays of the Sun and reflect them vertically downward to an object glass twelve inches in diameter lying horizontally just below the mirrors. This glass has a focal length of sixty feet, and forms an image of the Sun sixty feet below, six and one-half inches in diameter, in a laboratory at the base of the tower. In connection with these mirrors is a spectroscope over thirty feet long, which extends down into a deep well, with concrete walls beneath the floor of the laboratory.

Any of the peculiar disturbances on the Sun, such as the flames at its edge and the sun-spots, may be investigated by means of this spectroscope. The tower telescope embodies many new features, and the preliminary

tests show that it will prove superior to the Snow telescope, which is horizontal. It will be used exclusively for work on the Sun.

Besides the tower and Snow telescopes, Professor Ritchie has completed the work on a great sixty-inch mirror, which is expected to be more powerful than any optical instrument now in use. Professor Hale then explained to his audience the work on the Hooker telescope, of which the mirror is 100 inches, or more than eight feet across. The glass disk is now being cast in France, and when completed will weigh more than four and one-half tons. The sixty-inch glass, will be in place next summer, but it will be several years after this when the Hooker lens will be in place and ready for work.

Rev. Tilton C. H. Bouton, Henniker, N. H., writes of the interest awakened in the high school of that place on account of his setting up a 5-inch telescope for personal study in the elements of practical astronomy. In a letter of the fourth ult. he says:—"I give to the local High School the use of my equipment. As a result astronomy has been reinstated in the course of study in the English department, and a class is now receiving instruction. I wish the subject were taught in an elementary way in every High School and Academy. While on a vacation in August I was surprised to find the interest I was able to awaken, in a score of people, where I was stopping, and the wonder and pleasure which they showed in viewing a few celestial objects by the aid of a spy-glass with an objective one and seven-eighths inches aperture, using a power of about fifty diameters."

This is only one of many testimonials that might be cited to the same effect, regarding elementary astronomy and the way to teach it in secondary schools. The reason why this, the noblest, the most inspiring branch in all natural science is thrown out of nearly all high schools in this country, is the shameful fact that teachers do not know how to teach it, if they know anything at all about the subject.

Harvard College Catalogue of Variable Stars. In answering some queries for information concerning variable star catalogues, made of us recently by a correspondent, we omitted to mention the *Second Catalogue of Variable Stars* prepared by Miss Cannon, which forms Part I of Volume LV of the Annals of Harvard College Observatory. Probably Professor E. C. Pickering, Director of the Observatory could supply that Catalogue separately to any one in need of it.

Perth Catalogue of 420 Standard Stars. We have undertaken the zone $32° - 40°$ South declination for the International Photo Durchmusterung. Nearly all the necessary photographs (for the catalogue portion) have been taken, but the measurement is only now being commenced.

In all probability we shall not be able to take the long exposure photographs for mechanical reproduction.

In order to obtain the plate constants three stars have been selected, where practicable, in every square degree, and these are being observed with the transit circle. This work was commenced on October 6th 1901. Each observation consists of transits over seven vertical wires and readings of four microscopes. The instrument is a modern one of Messrs. Troughton & Simms, having a clear aperture of six inches. The "seeing" is usually good and the definition excellent.

The old method, which was first adopted, of determining clock error

from equatorial stars of the Nautical Almanac, and the nadir point from reflections over the mercury trough, was not considered satisfactory and was definitely abandoned on 1905, July 28th., after we had completed zones 32°, 33°, 39°, and 40°, and part of 33° – 34°. It was then determined to obtain both clock error and equator point from standard stars situated within or close to the zone of observation. Auwer's "Fundamental Catalog für Zonenbeobachtungen an Südhimmel" was accepted as the basis of the system but since at least three reference stars per hour are required for each zone of 2° it was necessary to choose a number of stars to act as Secondary Standards, and to observe these a considerable number of times. This has been done and the present catalogue is the result. It will be adopted as fundamental in the zone reductions until the whole zone 31° – 41° is completed and the results previously obtained between 1901, October 6 and 1905, July 28 will be reduced as well as possible to the present system.

In a few years a satisfactory determination (three complete observations) of the positions of some eight to ten thousand stars fairly well distributed over the region 31° to 41° will be obtained, and these will be used for the determination of the plate constants in the astrographic catalogue.

And now a few words as to the future of transit work. I have adopted a plan which I hope to see copied by a number of other observatories. I propose that the Perth Observatory shall confine its transit observations to this particular region and prepare a catalogue of exactly the *same stars* every ten or twelve years, or as frequently as possible, including each time a redetermination of the 420 secondary standards. Thus in course of time the worker in this part of the sky will turn to the Perth catalogues with the certainty of finding a number of stars in any ordinary sized field all of whose positions have been regularly determined from time to time and can therefore be brought reliably up to date.

Notwithstanding the millions of observations which have been taken and the hundreds of existing catalogues there are very few parts of the sky in which the above conditions exist. It is earnestly hoped that this attempt to place meridian work upon a more satisfactory basis may be followed by others, so that the output of energy may be concentrated upon some systematic measuring of the sky instead of being squandered as it has to some extent been in the past. In particular I hope that when their present program is finished the four Australian observatories will co-operate in order to maintain a systematic survey of the region 20° to 60° South declination.

W. Ernest Cooke.
Government Astronomer for West Australia.

New Photographic Meridian Telescope of the Paris Observatory. A new instrument for the determination of right ascension has been provided by Professors Ebert and Mascart for the Paris Observatory. It was designed by Professor Lippmann and it was constructed by Gautier, the new feature, in the main, being to use photography for getting meridian transits of stars to determine their right ascensions fundamentally.

The principle on which this new photographic telescope works for meridian results can be readily understood with a brief explanation.

A collimator is directed in the plane of the meridian and a cylindrical mirror with its axis normal to that plane is placed in front of the lens of the telescope. The rays from the illuminated vertical slit in the other end of the collimator will be spread out by the mirror into a plane sheet which will intersect the celestial sphere in a meridian circle. If these rays fall on an object-glass of a telescope, visual or photographic, which at the same time receives the light from a star, the image of the latter will be formed in the focal plane together with the line which represents the image of the great circle of the heavens (the circle of reference) traced by the luminous sheet reflected from the cylindrical mirror.

The telescope is mounted equatorially, in order to make long photographic exposures when desired. The diameter of the object-glass of this instrument is 6.3 inches. The slit of the collimator is provided with an instantaneous slit worked by clock-work once each minute. The field of view of the instrument is 180 degrees, and stars of the ninth magnitude can be photographed in twelve minutes. The plates show the star images and the black meridian lines for each minute. These data are said to be sufficient to give the star places with reference to the meridian within $\frac{1}{10}$ of a second of arc, or less than $\frac{1}{100}$ of a second of time, bringing out about 30 stars on each photographic plate.

The amount of electric light falling on the slit is regulated by hand, and that from the electric arc is used because it is more steady, all other light being shut out from the sensitive plate.

Professors Mascart and Ebert are now planning some improvements for this new method of star photography in order to give it wider application in several ways in the broad field of work opening before them. The advantages of this new instrument seem to be many, and meridian star places are likely to be improved and soon to be greatly extended.

The Zeigler Polar Expedition. The scientific results of the Zeigler Polar Expedition have been published in a fine volume of 630 pages under the auspices of the National Geographical Society by the estate of William Zeigler, Washington, D. C. The contents of this volume are an introduction by Anthony Fiala, magnetic observations and reductions, notes and sketches in colors of the Aurora Borealis, meteorological observations and compilations, tidal observations and reductions, astronomical observations and reductions, and map constructions and survey work.

A large part of this volume is given up to the magnetic observations and notes and finely colored sketches of the Aurora Borealis. The report is unique and valuable in this respect. The meteorological work in tabular form and graphical representation is full and useful for reference in high northern latitudes. The tidal observations and results also form an interesting feature.

On the inside of the right hand cover of the book is a large pocket containing three beautiful maps which will be highly prized by any one interested in a study of the north polar regions. It is named a Map of the North Polar Regions. It is 18 inches square and printed in delicate tints. It contains a multitude of historical and other references and geographical explanations which make it a most valuable reference map for almost all kinds of scientific knowledge as far as ascertained in this field of inquiry. The other two maps are of Franz Joseph Archipelago and locally interesting. The officers of this expedition are to be heartily congratulated on the success of this piece of work.

Report of W. F. King, Chief Astronomer of the Dominion Observatory at Ottawa, Canada. A bound volume of 283 pages is the report of Chief Astronomer, W. F. King for the year 1905. It is an interesting publication for it contains more information about the astronomical work recently done in Canada than has appeared in print before so far as we know. The names of the men on the working staff are known to many of our readers, for most of them have been referred to in this publication from time to time, especially Otto J. Klotz, J. S. Plaskett and Chief Astronomer King.

The report of Mr. Klotz on the transpacific longitudes which has been carried on under his direction is a paper of special interest. A general account of this longitude work across the Pacific Ocean with some illustrations of the island stations on the way would make a very useful article for the general reader as well as those more particularly interested in such astronomical work.

Mr. Plaskett's illustrated and descriptive report of the Observatory and its instrumental equipment, and his account of the observations of total solar eclipse of August 30, 1905 give clear and concise ideas of the important fields covered by the same. Mr. Stewart's description of the Time Service maintained by the Observatory gave us just the information desired in this line, because it was full enough to indicate a good and healthy existence although so near to the United States. Over here observatories generally have given up the public time service in which they were formerly engaged because the Western Union Telegraph Company has driven them from the field.

This report is a credit to those making it and to the observatory from which it comes.

Astronomical Papers for the Nautical Almanac. We are pleased to get the catalogues of zodiacal stars for 1900 and 1902, reduced to an absolute system, which is Pt. III, Vol. VII of the Astronomical Papers which are being prepared from time to time for the American Ephemeris and Nautical Almanac, and published by the authority of Congress.

This paper was prepared by Henry B. Hendrick, an assistant on the American Ephemeris, who commenced the work in 1899 by the authority of the late William Harkness, then Director of the Nautical Almanac. It was carried on by Henry D. Todd, S. J. Brown and Walter S. Harshmann, respectively, of the Nautical Almanac, as fast as the routine work of the office would permit. This catalogue contains 1098 standard clock and zodiacal stars which will be useful also in observing occultations in the future. In making this catalogue the following classes of stars were examined for sufficient observations:

1. All the stars within eight degrees of the ecliptic in the *Catalogue of 1098 Standard Clock and Zodiacal Stars* compiled under the direction of Professor Simon Newcomb and published as *Astronomical Papers of the American Ephemeris*, Volume I, Part IV.

2. All the stars in Dr. Downing's list *834 Zodiacal Stars selected for use in the Nautical Almanac* and published as an appendix to the British Nautical Almanac for 1897.

3. All the stars of the 7.5 magnitude and brighter within eight degrees of the ecliptic in the *Catalogue of 2798 Zodiacal Stars for the epoch 1900* selected and compiled under the direction of Dr. David Gill, at the Cape of Good Hope, in accordance with resolution 9 of the *Conférence Internationale des Étoiles Fundamentales* held at Paris in 1896.

4. All the stars of the 7.0 magnitude and brighter within eight degrees

of the ecliptic contained in Argelander's and Schönfield's *Bonn Durchmusterung* and in Thome's *Cordoba Durchmusterung.*

After examination of the adopted catalogues all the stars of which there were sufficient observations were included in the final list.

Also some stars, although not well observed, were included for one or more of the following reasons:

(*a*) If the star was contained in the first or second class given above.

(*b*) If it was a bright star and near the ecliptic.

(*c*) If it was contained in the older catalogues and needed modern observations, especially in the case of stars contained in Gill's Catalogue, as these will, in the immediate future at least, be more observed.

In all, more than 2500 stars were examined, of which about 900 were excluded for insufficient observations, and of the remainder at least 1000 are so well determined as to be regarded as fundamental.

The catalogues employed in the work were reduced to the same absolute system as that of Newcomb's *Catalogue of Fundamental Stars*, and all available positions in that catalogue are given in the present catalogue for 1900 without change.

The final solutions that were computed in this office and the computations of all the proper motions, secular variations, and star constants were done in duplicate. The copy for the printer was prepared from one set and the first type proof read from the other. In every particular the utmost care has been exercised to render the completed work free from error.

Dr. A. M. W. Downing, Superintendent of the British Nautical Almanac, upon notification of the commencement of the work, volunteered his assistance, and the final solutions of the equations of condition for all stars in classes 1 and 2 were performed under his direction with great efficiency.

Acknowledgments are due also to Professor E. C. Pickering, Director of Harvard Observatory, who kindly communicated photometric magnitudes of stars not contained in Volume XLV of the *Annals of Astronomical Observatory of Harvard College*, from which the magnitudes in this catalogue are taken, and to W. H. M. Christie, Astronomer Royal, who furnished advance sheets of the *Greenwich Second Ten-year Catalogue of Stars* for 1890.

Terrestrial Magnetism during the Total Solar Eclipse. In October *Knowledge*, some interesting conclusions have been reported regarding the effect of a total solar eclipse on terrestrial magnetism by C. P. Butler. Three are named which closely correspond with observations of this kind taken at different places. They are:

(1) The elongation of the needle to the west of the equilibrium position during the whole course of the eclipse was considerably less than the mean elongation; (2) none of the other curves recorded at one place (on other days) during the above period show this peculiarity; (3) at the exact moment of totality, corresponding to the usual maximum elongation to the west, there is shown a well accentuated minimum.

From this it will be seen that the effect of the eclipse is to cause a deflection of the needle to the east. The symmetry of the minimum and maximum of the curve proves that the magnetic effect accompanying the eclipse was of practically equal magnitude at the two stations at the moment of their respective totalities. The deflection at one place amounted

to about 3′ to the east, whereas normally the needle at eclipse time should be about 5′ to the west of its mean position. M. Nordmann proposes to explain this phenomena by the direct action of the Sun's heat on the Earth's atmosphere. The upper air currents will be altered in electrical conductivity when they are immersed in the shadow, and this variation crossing the Earth's magnetic field may induce sufficient electromotive force to influence the declination needle. In support of this view is cited the fact that the daily variation does follow the insolation almost exactly. On this idea the effect of the eclipse is not to produce an actual deflection to the east, but to diminish the action of whatever factor produces the westerly daily variation.

The Dimensions of the Andromeda Nebula. Assuming the parallax 0″.17 determined for the Andromeda Nebula by Mr. Carl Bohlin of Stockholm (See P.A. No. 151 p. 96), to be correct, I have been interested in a rough calculation of the dimensions of the nebula. Using the ordinary formula for the distance of a star,

$$D = \frac{R}{\sin p''} = R \times \frac{206265}{p''}$$

and assuming R to be 93,000,000 miles, we have for the distance of the center of the nebula from the Sun roughly

$$D = \frac{93{,}000{,}000 \times 206{,}265}{0.17} = 113{,}000{,}000{,}000{,}000 \text{ miles.}$$

From measurement of my 12 hour photograph of the nebula I find the length to be approximately 1° 49′ and the width to be 29′. Assuming that the longest line through the nebula is perpendicular to the line of sight, from the Earth to the center of the nebula, we have for its longer dimensions

$$L = 113{,}000{,}000{,}000{,}000 \times 2 \tan 54.'5 = 3{,}600{,}000{,}000{,}000 \text{ miles.}$$

That is, the extent of the Andromeda Nebula is more than 600 times that of the orbit of the Neptune.

If the spirals of the Nebula are nearly symmetrical, lying in the same plane and the elongation is merely due to the foreshortening of one dimension by perspective, then the inclination of the plane of the spirals is about 15.°5.

The parallax used in the above calculations must be regarded as extremely uncertain, and the conclusions drawn therefrom should be given little weight, but they may help to give the reader a slight conception of the enormous extent of one of the most wonderful objects in the heavens.

The Crookston Meteorite—On the evening of Jan. 4, at 7:45 p. m., the people of Crookston, Minn., were terrified by the great brilliancy and sudden bursting into many fragments of what appeared to be a great meteorite, not far away. The dazzling light continued for more than 30 seconds. It was so bright as to frighten horses and make them unmanageable. We can not yet learn that any sounds of a detonating kind were detected in the terrific roar accompanying the display. Though searched for, no fragments have yet been found.

Meteoric Shower. On 1907 August 15 I saw five meteors during a watch of forty minutes from a radiant at 288° + 61°. One of them was stationary at that point. On August 26 at 9^h 18^m I observed a brilliant member of the same shower falling from 231° + 57° to 213° + 50°, and showing some curious fluctuations in its light. On August 28, during a short period of clear sky, I recorded two other meteors from the same radiant. On August 15, Mr. H. Corder saw a Draconid equal to Mars flashing out with an orange color at 288° − 10°, and falling 8° further in a vertical path directed from a point one degree west of β Cygni.

The shower is evidently active between August 15 and 28, and I recognized it between these dates in the years 1887, 1899, and 1900. Mr. Corder had also seen it pretty richly manifested on 1879 August 16 from 286° + 61° (10 meteors).

This display of Draconids, coming, as it does, concurrently with the rapidly declining stages of the great Perseid shower, deserves special mention, and particular efforts should be made in future years to re-observe it. In 1879 August 21 to 25, of 225 meteors which I recorded, no less than 56 were Draconids, and nearly all of them were bright, slow-moving objects with yellow trains. During the twenty-eight years which have passed since 1879 I have never seen the shower richly exhibited until last month, when, however, my observations were very imperfect on account of ill-health. Particulars of this evidently prominent and periodically visible system of meteors, as it appeared in 1879, will be found in the MONTHLY NOTICES vol. xl. pp. 127-8, and in THE OBSERVATORY, vol. iii. pp. 172-3.

W. F. DENNING.

From MONTHLY NOTICES, LXVII, No. 9.

Solar and Planetary Physics and Motion—We have received a neatly printed pamphlet of more than 50 pages, titled: "Solar and Planetary Physics and Motion," by Edward Lynch, of Alameda, California. We notice that the pamphlet is dedicated to the memory of John M. Gregory first president of the University of Illinois, which at once brings to our minds, very freshly, the noble record that Dr. Gregory made in Michigan before going to Illinois.

The pamphlet is one of very unusual interest because of the research work in it on lines of study that have taxed able scholars for many years past and probably will continue to do so for many years to come. We are glad the author has titled these chapters as preliminary, because the suggestions they bring out can not be thought of as more than that, for the problem to be solved, and herein hinted at, is by far too difficult for more than plausible inference from the data that science has yet collected and helpfully arranged. To predict terrestrial meteorology for months and years to come from solar and planetary physics and motion, or from any other sources, is a thing to be sought after very earnestly, wisely and diligently.

In this direction the author has gathered much information, tabulated a mass of it, as well as he could, done a lot of interesting graph work in which he is plainly at home, and then based on all this information the supposition that the planets have influence enough in the Sun possibly to cause weather changes, electrical storms, earthquakes, and other phenomena of a similar kind. The many and interesting facts that the author has collected, arranged and tabulated, doubtless have a place and important meaning in terrestrial meteorology, but we fear no one can certainly claim for them yet quite so much as the author seems to see in them as the cause or causes of terrestrial influence for time predictions, for the reason that it is not yet proved that such things show sufficient cause.